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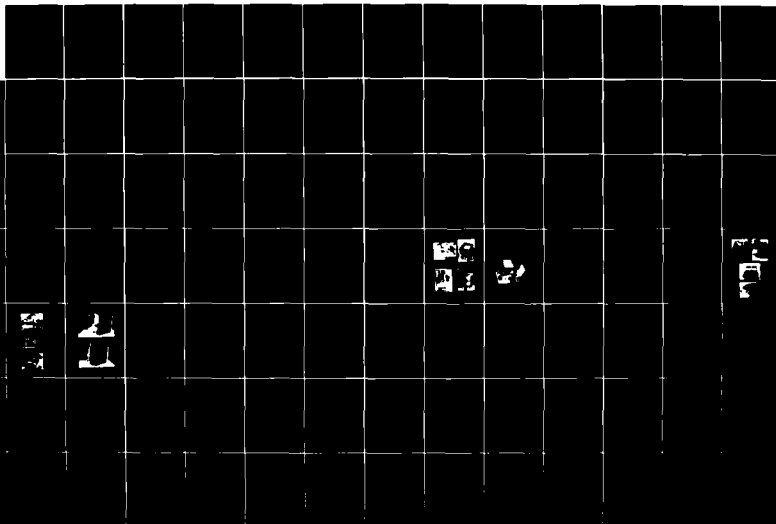
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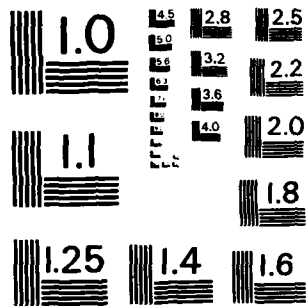
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RUGGEDIZED VIDEO DISPLAY SYSTEM

January 1984

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Dayton, Ohio 45404

FINAL REPORT

Contract No. DAAG46-81-C-0007

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Watertown, Massachusetts 02172

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ABSTRACT

↓ A method of protectively mounting a cathode ray tube (CRT) and an electronic "drawer" in a video terminal utilizing a system of molded rigid and flexible urethane foam is described.)

(As a demonstration of the capabilities of the urethane foam suspension system to protect the CRT and electronics, a series of CRT packages and complete video terminals were designed, fabricated, and tested and shown to be successful.
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EXECUTIVE SUMMARY

This report outlines a program undertaken to design, fabricate and test a system for ruggedizing standard commercial video hardware, particularly commercial 15 inch cathode ray tubes, so that they can survive the severe environmental extremes associated with military field use.

Key to the achievement of the program's objectives was the uniform distribution of shock-imposed loads through the tube's structure. This was done by encapsulating the tube in rigid molded urethane supported by molded flexible urethane pads. The video terminals manufactured using these techniques were subjected to severe environmental stresses, the most significant of which were drop tests.

Following 26 drops from 4 feet on each face, edge, and corner of the system, these terminals continued to function normally.

Thus the effort demonstrated that a video terminal entirely based on commercial electronics and hardware can be ruggedized for military transport and use, using straightforward inexpensive means and that the adaptation of the technology is complete and ready for a development effort on a specific piece of operational equipment.

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FOREWORD

The technical effort covered in this report was performed by Centro Corporation, Dayton, Ohio for the Army Materials and Mechanics Research Center, Watertown, Massachusetts under Contract No. DAAG46-81-C-0007, Ruggedized Video Display System. Funding for the program was provided by the Army Communications and Electronics Command, Fort Monmouth, New Jersey. The COTR was Mr. Peter Dehmer, Office Symbol DRXMR-OC, Composites Development Division. This report describes the analysis, design, fabrication and evaluation efforts performed from 14 November 1980 to October 1983.

The author acknowledges the assistance of Mr. Dehmer and Mr. David Hadden, Office Symbol DRSEL-TCS-CR, Army Communications-Electronics Command, for their correlations of the contract objectives and specifications with the design and operational requirements of the equipment developed in the program.

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I. INTRODUCTION

This report summarizes the design, fabrication, and testing of Ruggedized Video Terminals for use in severe or hostile military environments. The techniques developed and tested during this program demonstrate the capability to adapt and protect standard commercial video hardware, such as CRT's, keyboards, etc. so that they will survive severe environmental extremes associated with military field use.

The environmental extremes investigated include primarily severe shock and vibration but also have included temperature extremes and exposure to fungus.

The unique protection system developed to achieve this goal uses a system of rigid molded urethane encapsulation and flexible molded urethane pads to isolate, support, and protect the CRT and electronics.

The program described herein has progressed from the successful demonstration of a design to protect a 15 inch commercial CRT against environmental extremes through the design, construction and testing of a complete "glass teletype" video terminal, including CRT, keyboard, and electronics.

The resulting video terminal is entirely based on adapted commercial grade electronics and hardware and is a complete "stand-alone" device, including an impact resistant plastic case.

The techniques developed in this program offer a straightforward means to inexpensively package delicate devices for field transport and use.

II. DESIGN CONCEPT

With the rapidly expanding commercial market in microcomputers and small computer terminals, a large manufacturing base has been developed for computer components. The competitive nature of this market has produced very high quality components at relatively low prices and very good availability. For example, commercial cathode ray tubes for high resolution monochromatic terminal displays are produced by several manufacturers in a wide range of sizes and phosphor types.

The larger versions of these tubes offer the capability of displaying a large amount of alphanumeric information in a highly legible form. By combining this display capability with the ability to edit, transmit, and receive information over land lines, and to produce hard copy by peripheral printer, an effective field communication system can be developed.

While the commercial CRT's manufactured today offer high resolution and low cost, they are not constructed to withstand severe environments that might be associated with battlefield deployment. The glass envelope which makes up the outer shell of a cathode ray tube is subject to fracture or implosion due to shock or vibration loads. The neck of the CRT which, due to the manufacturing process and the requirement to dissipate filament heat, is very thin and fragile, must support a relatively heavy external magnetic deflection yoke. In addition, the electron "gun" structure, housed within the neck of the tube, must maintain precise alignment to insure accurate image focus and location.

There are some military ruggedized CRT's available which are designed to survive shock and vibration, but they are typically one or two magnitudes more expensive than commercial grade components and they are not widely available. Ruggedized military CRT's incorporate somewhat sturdier glass envelopes, heavier gun structures, and are typically housed within relatively close fitting metal outer cases. These cases provide support for the glass envelope.

If a commercial grade CRT could be protected from environmental abuse by isolating it within the terminal case, a low-cost, rugged data communication device would be possible. The basic requirements for a system or method which will isolate a CRT or other delicate device from damage due to shock or vibration are that the isolator must be capable of deflecting under load and it must be capable of dissipating the energy stored due to deflection. In addition, a means must be provided to distribute external loads imposed by mounting conditions and inertia loads due to the mass of the various CRT elements.

Flexible foams are widely used as packaging materials for the protection of fragile items. In most of these applications, the protective foam is

cut in sheets or blocks from bun stock or other larger pieces, or in the case of two-part low density urethane, the material is formed in place around the item to be protected, which has been wrapped in plastic film prior to foaming. This latter type of foam is actually a very low density, semi-rigid material which has some resiliency, but which undergoes permanent crushing when severely deformed.

There exist, however, types of low to medium density flexible foams which can be molded into shapes which can be designed to provide energy absorbing capability. A means devised to attach flexible foam supports to a CRT, as well as a way to distribute loads imposed on the CRT, is to encapsulate the CRT, along with the magnetic deflection yoke in a rigid, but lightweight, molded foam block. The block would provide support for the CRT neck, stabilize the deflection yoke, and provide a uniform external shape to attach flexible foam isolators.

The terminal case provides weather protection for the CRT and electronics and must withstand the effects of impacts and scrapes due to rough handling. Certain plastics offer excellent resistance against impact damage and abrasion. In addition to the use of flexible and rigid foams for isolation and protection of the CRT and electronics, thermoformable plastic sheet can be formed to provide a rugged, low manufacturing cost case.

III. PROGRAM OUTLINE

The Ruggedized Video Terminal program was divided into five phases. Each phase was designed to build upon and verify the results of the preceding phases and to expand the technology base by investigating a new aspect of the overall terminal package design.

The initial objective was to demonstrate that a mounting and suspension system, using molded elastomeric foam, could be developed which would protect a standard commercial grade high-resolution 15 inch cathode ray tube and magnetic deflection yoke against the environmental extremes imposed by a series of MIL-STD-810C tests.

These tests included: High Temperature (501.1), Low Temperature (501.2), Temperature Shock (503.1), Fungus (508.1), Vibration (514.2) and Shock (516.2).

Subsequently, the techniques developed to protect the CRT were employed to protect an electronics "drawer", and an impact resistant formed plastic case was developed to contain the complete video terminal. The entire terminal was subjected to the same MIL-STD-810C tests as the CRT.

Phase I of the program was concerned with the selection of a representative commercial CRT, the selection of the protective materials to be used, development of the protective design approach, and preliminary design of experimental tooling.

Phase II of the program was concerned with the construction of tooling, fabrication of preliminary test specimens, shock testing of one CRT specimen, and planning comprehensive testing of additional specimens.

Phase III of the program consisted of the construction and comprehensive environmental testing of two protected CRT specimens and the preliminary design of a complete ruggedized video terminal, incorporating the protective methods previously developed to mount the CRT and the complete terminal electronics package.

Phase IV expanded the selected preliminary design concept for a complete terminal into a complete detail design, including tooling and fabrication, and subjected a specimen terminal to a preliminary shock test.

Phase V of the program refined the terminal design on the basis of the Phase IV test and included the construction of four complete video terminals from the Phase IV tooling. One of these terminals was subjected to the complete sequence of environmental testing.

IV. PHASE I

1. CRT SELECTION

The first milestone in this program was the selection of a suitable commercial video monitor CRT that could be fitted with the foam based support system to be developed during the program.

The basic design approach was to obtain data from CRT manufacturers relative to the maximum shock and vibration a commercially available 15 inch CRT could tolerate and then design the foam support system to preclude developing any deceleration forces beyond this defined limit.

It was quickly determined that CRT shock and vibration data from commercial CRT manufacturers was nonexistent or poorly defined. Modern Packaging Encyclopedia places CRT's in the "Moderately Delicate" category with a maximum permissible shock load of 60-85 g's. This reference, plus discussions with tube manufacturers resulted in a decision to design conservatively for 50 g's.

The analysis to define the form and dimensions of the CRT support system that would meet this load limit resulted in an early determination that it would be very desirable to cast the CRT in a rigid foam block and use flexible foam to suspend and isolate this near rigid mass from the case.

While there is an electronics industry standard that defines the nominal envelope shape for a given CRT geometry, the manufacturing process apparently does not control these dimensions accurately except at certain points such as the perimeter of the tube face and the neck diameter. Therefore, by encapsulating the tube in rigid foam within a mold, the exterior dimensions of the resulting cube could be very accurately controlled.

In addition, this encapsulation technique has the major benefit that it prevents local loading from being applied to any portion of the CRT. With the CRT contained within a nearly rigid mass, the delicate CRT neck, ordinarily unsupported and cantilevered from the back of the tube, is protected from any bending stress or shear load due to its own mass or from the deflection yoke.

The magnetic deflection yoke, which is installed on the neck of the CRT, is normally secured with a clamp. By encapsulating the CRT, the yoke would be completely immobilized and could not theoretically become misaligned due to shock loads.

By providing a molded-in cavity in the CRT block for the high voltage power supply, the CRT anode lead could be entirely contained within the

CRT block and all high voltage sources would be isolated from the remainder of the terminal electronics.

This encapsulation is the key to successfully ruggedizing the commercial CRT.

It was apparent that retrofitting a foam support system into an existing commercial monitor case was not feasible because of volume constraints. It was decided to fabricate a custom case that would permit the evaluation of the support system by testing.

Once it was decided to encapsulate the CRT in a rigid foam block, it then became necessary to select a specific CRT. The choice of size and type of CRT to be incorporated into a video terminal involved a trade-off among several variables which are influenced by environment. These included: display size and shape, deflection angle, neck size, phosphor type, deflection method, focus method, and implosion protection. There are other design factors, such as operating voltages, brightness, phosphor persistence, etc., but they do not substantially affect, nor are they substantially affected by, the tube envelope or the operating environment.

The initial Army requirement regarding display size was for a 15 inch diagonal measure rectangular tube. This was a compromise between CRT package sizing and display space legibility, (120 characters/line, 24 lines/screen.) There is no industry-wide standardization of tube height and width for a 15 inch diagonal measure. However, most of the glass envelopes are made by only a few manufacturers, and a relatively common 15 inch tube measures approximately 12.6 x 10.1 inches. This aspect ratio (width/height) was chosen for this design.

The deflection angle has a major effect on spot size and brightness uniformity, deflection power, and tube length. Typical deflection angles are 70°, 90°, and 110°, with the 70° deflection tubes being typically very high resolution units. The most common tubes available are 110°, with 90° and 70° being each progressively less common. The overall length of the tube (which is also determined in part by neck size) ranges from perhaps 11 inches for a 110° tube, to 18 inches for a 70° tube. Considering size, availability, resolution, and price, a 90° deflection angle was selected as the best compromise.

For the complete terminal envelope that was later developed, the depth of the electronics drawer determined the overall terminal depth, rather than the CRT, so the 90° deflection angle was not a limiting factor in this case. This would not be true for a 70° deflection tube, however.

The neck size of the tube is determined primarily by convention. The standard size is 36 mm (1.437 inches) diameter. Deflection yokes are readily

available for this size. The desire to reduce power consumption has produced tubes with neck diameters of 28 mm (1.102 inches) and 22 mm (0.866 inches). These tubes are also shorter than the 36 mm tubes. However, they are substantially more difficult to obtain (as are add-on parts, such as yokes) and more significantly, the smaller gun structures require more precision in manufacture and assembly, and are more easily knocked out of alignment. For these reasons, a "standard" 36 mm neck diameter was selected.

There are many phosphor types available. The variables influenced by phosphor type are brightness, color, and persistence. Persistence is a measure of the time required for the decay of the visual signal and many range from .1 μ for flying spot scanners to up to 7 seconds for some PPI radars. Television and computer monitors have phosphors with persistence from 20 μ s to 2 ms. The P4 white phosphor has a persistence of 20-60 μ s and is used in black and white TV. It is readily available. The P43/44 yellow-green phosphor is used in computer terminals. It has high brightness and can be combined effectively with a contrast enhancement filter. The P43/44 phosphor was selected for this program.

The electron beam may be deflected either electrostatically (internally) or magnetically (deflection coils). The first method is limited to small deflection angles and generates spot distortion as a function of increasing deflection angle. Beam deflection by deflection yoke (magnetic) was chosen to maintain a reasonable tube length.

There are three methods of focusing for CRT's: high voltage electrostatic, low voltage electrostatic, and electromagnetic. For display systems, high voltage electrostatic focus is the preferred choice since this results in better spot size and spot size uniformity, reduces dynamic focus requirements, and permits a shorter gun.

Implosion protection is necessary to prevent the accidental discharge of broken glass when the terminal is deployed for use.

Implosion protection was provided by a metal tension band mounted around the perimeter of the tube face. The tension band is installed by the tube manufacturer. In a production configuration, the tension band would be combined with a tempered glass or plastic panel adhesively bonded to the face of the tube. This panel could also incorporate a contrast enhancement filter.

Figure 1 is a scale drawing of the selected Clinton 15 inch CRT. This particular tube type was used throughout the program and is representative of 15 inch tubes built by several manufacturers.

2. FOAM SELECTION RATIONALE

There are a number of plastic foams available which offer energy absorbing properties. The most common types are styrenes, polyethylenes, polyvinyl-chlorides, urethanes, and synthetic rubbers.

All of these foams are formed by introducing a gas or blowing agent into the melt and allowing the melt to expand, either freely or into a mold. The blowing agent may be introduced by direct injection into the mold, or may have been previously introduced into solution within the polymer melt. In the latter case, the gas is liberated by the application of heat and/or expansion due to reduction of high pressure to atmospheric conditions.

Urethane foams are two-part polymers (a polyol and an isocyanate) and they are unique in that the blowing agent, which may be in solution in the polyol (typically "freon") or which may be formed by a reaction between water in the polyol and the isocyanate (carbon dioxide), is liberated and expanded by exothermic heat of reaction when the two components are combined at the time of injection into a mold. The resulting foam is a thermoset, which, depending on formulation, can be made soft and flexible or firm and rigid at equivalent densities. These foams, made from either polyester or polyether compounds are strong, even at low densities, and have good chemical resistance, being relatively immune to most solvents. Furthermore, the foam materials offer no nutritive value to microbes and fungi.

All of the various plastic foams, except the urethanes, require rather high temperatures and pressures to achieve satisfactory expansion. Typically, even the so-called low-pressure foams require molding temperatures of 300°F and blowing pressures of 200 to 500 psi. This requires heavy, metal faced, reinforced molds for fabrication. Furthermore, in an application such as CRT protection, because of the high temperatures and pressures which would be required, it is questionable whether such foams could be safely molded around a CRT held in the mold, without damaging the CRT. This means a separate step would be required to bond the foam material to the CRT which would require close tolerances to match the molded foam to the CRT contours.

On the other hand, temperatures and pressures required for urethane molding are quite moderate. Temperatures rarely exceed 150°F and pressures vary from 20 to 60 psi, depending on the packed density of the foam material. Furthermore, the urethane material, in its uncured state, has very tenacious adhesive properties. This makes it feasible to fabricate low-cost, epoxy faced development molds with simple backup structure, and to capture the CRT in the mold and cast the rigid foam material directly on the tube, with no separate bonding step.

Urethane foams are available from several commercial suppliers, in many standard formulations. Prices for the polyol and isocyanate range from \$4.00 to \$5.00 per pound in small quantities to around \$1.00 per pound in bulk quantities.

Offsetting the advantages of urethane foams, compared to some other plastic foams, are a tendency to be dimensionally somewhat unstable with time, and a tendency to degrade (harden and crumble) when exposed to ultraviolet light. The former tendency is not considered to be a serious problem in this application because of the compressive nature of the flexible foam. Since most of the foam will be contained in a light-tight case, it will not be exposed to ultraviolet light. The foam which surrounds the tube face could be protected by a barrier coat (flexible paint) or an ultraviolet screening chemical could be introduced into the polyol before mixing.

The fundamental approach to protect a CRT against shock and vibration is to convert the energy possessed by the moving CRT into work required to compress a series of foam pads. The stored energy in the compressed foam must ultimately be dissipated as heat.

All flexible foams are capable of storing energy by deflection, but the most effective foams for dissipating energy are ones in which the structure is predominately open-celled. In fact, while the mechanism is not entirely understood, it has been shown that flexible urethane foam is a particularly efficient dissipater of stored energy (i.e., there is substantial hysteresis in a stress vs. strain curve for this material).

It is clear from experiments performed by other investigators that the energy is dissipated both through the flexing of the microcellular material and the friction of the air moving through the open cell structure.

Because of its efficient damping characteristics, its wide range of elastic properties, and because of its ability to be molded with low-cost tools, flexible urethane was selected as the foam material to be used to protect the CRT.

3. DESIGN FOR SHOCK AND VIBRATION

The most severe requirements imposed on the CRT package by MIL-STD-810C are those related to shock and vibration, and in particular, the drop test associated with loose cargo. Shock and vibration behavior are related, and in fact, shock loading is really a special case from the general spectrum of vibrations which may affect the CRT package. However, because of the severe shock test parameters (48 inch drop, 26 drop aspects) it is the shock loading which will primarily design the package.

The load factor, or ratio of applied shock force to component weight, which can be tolerated by a CRT depends on the point of application of the load and the design of the internal CRT components. The two types of failure which are possible are: 1. fracture of the glass envelope, 2. damage to or misalignment of the gun assembly.

The glass envelope has a very large variation in wall thickness and therefore, relative strength, depending on location. The perimeter of the tube, around the face, is quite thick and strong. This is the usual area where mounting loads are applied. The neck of the tube, from the deflection yoke mounting location to the pin connector, is very thin and fragile. If this area were not adequately supported, shock loading induced by the deflection yoke could easily break the envelope.

The gun assembly is perhaps the most delicate portion of the CRT, and because it is sealed inside the tube, it cannot be directly reinforced. Depending on design, it is capable of withstanding perhaps 60 g's in standard CRT's to 100 g's or more in special ruggedized MIL-SPEC tubes. The gun assembly, by the nature of its configuration is capable of tolerating more shock parallel to the neck axis than it is perpendicular to the axis. According to the limited shock tolerance data available, ordinary home color CRT's are capable of withstanding significantly more shock and vibration than monochromatic CRT's. Apparently this is because the requirements for maintaining precise mutual alignment of three guns in a color CRT necessarily require a more rugged gun assembly.

To insure a conservative approach to design of the CRT packaging system, it was assumed that the maximum allowable load factor which could be tolerated by the CRT at any time is 50 g's. This is a compromise between published allowable shock data of 60-85 g's for televisions and 40-60 g's for computer equipment. As will be seen later in this report, it is relatively simple to adjust the package design for different acceleration levels.

Consider the following shock analysis, which assumes a mass-spring relationship with no damping:

For a mass (such as the CRT block) supported on a flexible foam cushion,

assume that the relationship between the applied static pressure, or stress, on the foam material and the resulting strain obeys the following equation:

$$p = a\epsilon^b$$

where p = applied stress or pressure

ϵ = strain, or ratio of deflection
to total thickness of material

a, b = coefficients depending on
the material

Note that for a perfect spring, or a material which obeys Hooke's Law, $b = 1$, and for a material which crushes under a specific applied force, $b = 0$. For the actual urethane foams used, the value of the coefficient "b" is different for the different ranges of strain and for different densities. At small deflections ($\epsilon < .1$) the value of "b" is typically less than 1.0. At large deflections ($\epsilon > .5$) the value of "b" is more than 1.0. However, over a fairly broad range of deflections ($.1 < \epsilon < .5$) the value of the coefficient "b" is very nearly equal to 1.0 (see Figure 2).

The coefficient "a", which would be called the "modulus of elasticity" for most materials with linear behavior, is referred to as the "elastic constant" in packaging design. The value of "a" for flexible urethane foams is a function of formulation and molding density.

When a package, such as the CRT, is dropped from a height, the potential energy initially possessed by the package is converted into kinetic energy. The packaging material converts the kinetic energy into work done in compressing the foam:

$$W(h + \Delta x) = A \int_0^{\Delta x} a\epsilon^b dx \quad (\text{neglecting damping forces})$$

where: A = pad surface area

W = weight of package

h = drop height

Δx = maximum foam deflection

a, b, ϵ = as before

Rewriting ϵ as $\frac{x}{t}$, where t = pad thickness, and dividing by A :

$$\frac{W}{A}(h + \Delta x) = \int_0^{\Delta x} a \frac{x^b}{t^b} dx$$

If we assume that the coefficient "b" is constant over the deflection range of interest, the integral can be evaluated as:

$$\frac{W}{A} (h + \Delta x) = \frac{a}{b+1} \frac{\Delta x^{b+1}}{t^b}$$

But $a \left(\frac{\Delta x}{t} \right)^b = P \max = \frac{nW}{A}$, where n = maximum applied "g's".

Substituting and solving for Δx :

$$\Delta x = \frac{h(b+1)}{n-b-1}$$

Thus, the required compression distance for the energy-absorbing medium (foam) is dependent on the drop height (h), the maximum allowable deceleration or "g's" (n), and the energy absorbing behavior of the material (b). Note that the required deflection is independent of the elastic constant or stiffness of the foam (a).

This simple analysis has neglected damping forces and assumes that stress is a monotonic function of strain. Neither assumption is strictly true, but the simple equation gives insight into the amount of foam material required. If the maximum deflection of the foam is below the second inflection point (i.e., $b \geq 1.0$) the predicted required foam thickness will be conservative.

A series of simple load-deflection tests were performed on samples of a certain manufacturer's flexible foam. These tests were done on a foam formulation with a nominal free rise (unconstrained) density of 3 lbs per cubic foot. The specimens were cast into 4 inch cubes in a simple mold, with different amounts of liquid material being poured into the mold to yield different mean densities.

Urethane foams have a tendency to densify near the surface of the mold to produce a "skin." The thickness of this skin is controlled largely by mold temperature; the higher the temperature, the thinner the skin. Some of the specimens were cast at room temperature, while others were cast in a model which was heated slightly by a radiant heater.

The results of these tests are shown for four specimens in Figures 2 and 3. A simple test apparatus, consisting of a die shoe to guide and stabilize an applied load of dead weights and a spring micrometer to measure

deflection, was used. The results are plotted as applied load or pressure, equal to the total weight divided by the bearing area of the specimen versus percent deflection, or measured deflection divided by the initial block thickness, times 100. The test apparatus is shown in Figure 4.

These tests demonstrate that at very high and very low densities the material behaves in a nearly linear fashion, while at medium densities, the behavior is decidedly non-linear, and furthermore, is affected by the amount of skin formed on the specimen. This latter behavior is partly the result of the thicker skins acting as thin sheets in compression, partially stabilized by the flexible foam inner core. The skins fail in buckling, causing the foam to "load up" and producing non-linear behavior. The low density foam has very little skin to cause this phenomenon, while the high density foam behaves more nearly like rigid homogenous material.

It is important to note that this wide range of properties is produced using the same foam formulation, which means that padding cast for CRT protection can be significantly tailored to achieve the desired properties.

Assuming that the exponent, "b", in the relationship,

$$p = a \left(\frac{x}{t} \right)^b$$

is equal to 1.0 (conservative), and that the maximum allowable "g's" which may be imposed on the CRT is 50, and the drop height is 48 inches (per MIL-STD-810C), then the required compression distance is:

$$\Delta x = \frac{(48)(1+1)}{50-1-1} = 2.00 \text{ inches}$$

If it is assumed that the maximum allowable percentage of compression is 70%, then the relationship between weight of the CRT, surface area of the foam pad (at point of impact) and foam elastic coefficient is:

$$50 \frac{W}{A} = a(.70)^{1.0}, \text{ or: } a = 71.4 \frac{W}{A} \text{ req'd}$$

If the CRT package weighs, say 20 lbs, and the coefficient "a" has a value of, say 100, then the required pad area is:

$$A = \frac{71.4}{100}(20) = 14 \text{ sq. in}$$

Obviously, for any given CRT weight, the amount of pad area can be varied

depending on the value of "a", to limit maximum deceleration under shock load. However, if the pad is too stiff ("a" too large), the resonant frequency of the CRT/suspension system will be too high and may approach the natural frequency of the gun assembly. In order to limit this, the pad stiffness must be kept as low as possible.

The amount of pad area presented at impact, and therefore the required stiffness, depends on the drop aspect. MIL-STD-810C requires drops on each face, each edge, and each corner of the container, for a total of 26 drops.

The most critical aspect is the corner drop, because of the difficulty of providing sufficient projected cross-sectional area of the foam material, without exceeding the allowable pad area in other aspects, e.g., for drops on a face, the pads at four corners contribute to the net pad area for that face, while each corner pad acts independently for a corner drop.

This fact will typically cause the thickness of the pads which protect against face and edge drops to be greater than would be necessary if protection from corner drops were not required - the increased effective stiffness in face drops is offset by increased compression distance.

4. INITIAL CRT SUSPENSION DESIGN

The initial foam pad configuration was an attempt to minimize the effect of drop orientation. The design incorporated a CRT and deflection yoke encapsulated in rigid urethane. Four molded flexible urethane corner blocks were bonded to the rear corners of the CRT block and intermediate thin blocks were bonded to the long edges of the CRT block. A flexible foam bezel was installed to completely surround the face of the CRT. Large cutouts were molded in the perimeter of the bezel foam to optimize the ratio of foam area projected for side drops to that for front corner drops. This design is shown in Figure 5.

One aspect of designing the foam suspension for shock loading which has been accounted for in only a very approximate fashion is the tendency of the foam to behave as a more rigid material under a shock impact, as opposed to a slowly applied load from which static deflection measurements are made. This is because of the inertia of the air contained within the cell structure of the foam. Since a finite time interval, even though a very short one, is required to get the air moving through the cells, each air filled cell initially acts as a tiny spring and accordingly the foam appears to be stiffer than static data would indicate. The typical method of treating this property is to apply a multiplying factor to statically measured values of the elastic constant. The multiplying factors typically range from 1.25 to 2.00.

As discussed previously, the value of the elastic constant for molded urethane can be controlled by varying the shot size, and hence, the density, of the foam as well as the formulation. The value of the elastic constant will determine the required pad surface areas to achieve the desired limiting accelerations. Fortunately, the multiplying factor causes the required static value of the elastic constant to be lower, and so the natural frequency of the system will also be lowered. This is desirable to isolate the system from vibration-induced damage to the gun assembly.

The molds used to form the various foam parts were designed to be constructed in highly modular fashion, largely from aluminum tooling plate. If, as a result of subsequent testing, dimensional changes were necessary, the molds could be disassembled and modified.

With the specific CRT and foam types selected, the preliminary suspension design defined, and simple tooling designed, all elements of the Phase I portion of the program were completed.

V. PHASE II

1. CRT TOOLING CONSTRUCTION

During this phase of the program simple tools were constructed to fabricate the foam CRT suspension system, foam parts were made, and CRT's were encapsulated. A preliminary series of shock (drop) tests were performed on a CRT and the foam configuration was optimized.

As was discussed in the preceding section, the basic protection concept for the CRT was to encapsulate the tube and deflection yoke in a rigid foam block leaving the face and a portion of the neck accessible. The special molded flexible foam pads were then bonded to the surface of the rigid foam block and the complete assembly was installed in a case.

All of the rigid and flexible foam parts to be used for preliminary CRT testing were fabricated in five simple molds. These molds were constructed chiefly of aluminum tooling plate and assembled with machine screws. Some mold parts were designed to be interchangeable between molds to minimize mold construction costs.

Foam parts were demolded by disassembling major portions of the various molds. In a production situation, molds would ordinarily be provided with built-in draft, clamp-on covers, push-out pins, and other features which would make the removal of finished parts a more simple operation. These features were not provided in the experimental molds to minimize cost, and also to simplify possible mold changes.

The mold used to encapsulate the CRT in rigid foam was a rectangular box constructed of aluminum tooling plate. A cast epoxy insert in the bottom of the mold was a close fit around the perimeter of the face of the CRT. The CRT was pulled against this insert by drawing a vacuum against the face of the CRT. An O-ring seal around the perimeter of the epoxy insert prevented foam from leaking through to the face of the tube.

A turned block in the top of the mold received the neck of the CRT, which was sealed by another O-ring. This block displaced foam away from the hot filament portion of the tube neck and supported the tube in the mold. The anode lead and deflection coil leads exited the mold through small holes in the top plate.

Figure 6 shows a CRT installed in the mold, ready for encapsulation. The sideplate is removed for this photograph only.

Four flexible foam molds were built during this phase of the program. One mold produced a flexible foam bezel which was to be installed around the face of the tube. A second mold produced a square foam block with one

corner relieved. Four of these blocks were glued to the rear corners of the CRT block. A third mold produced thin rectangular blocks which were initially glued to the edges of the CRT block. These parts were eliminated in later tests. The fourth mold produced a large foam part which was installed in the lid of the case. This foam block was contoured to fit against the foam bezel on the CRT block. A completely assembled CRT block with flexible foam pads bonded in place is shown in Figure 7.

2. DROP CONTAINER

A rugged case was constructed to house the CRT and foam pads during shock testing. This case was built as a weldment of aluminum sheet and angle stock with a removable front and back cover. This case was not designed to duplicate an actual monitor case, but was intended to be extremely durable (survivable) and very rigid, to minimize its own deflection and interaction with the foam system. It allowed the loads resulting from the shock tests to be distributed completely through the foam with negligible energy being absorbed by the case itself.

3. FOAM SELECTION

In the Phase I portion of this report, a discussion of the various characteristics of flexible urethane foams as energy absorbers was presented. As a result of analysis and testing of several foam samples, a medium density, high energy absorption, high load-bearing foam system manufactured by Freeman Chemical Corp., (Port Washington, Wisconsin) was selected to mold the various flexible pads. A specification for this material is included in Appendix A. This system has a free rise density of 3.0 lbs per cubic foot. This material had an as-molded density of about 4.5 lbs per cubic foot in the parts fabricated in this program.

The rigid foam material selected to mold the large block around the CRT is a 2.0 lb per cubic foot free rise density system manufactured by Stepan Chemical Co., (Northfield, Illinois). This material, which has a substantial self-skinning characteristic was molded around the CRT to a density of about 5 lbs per cubic foot. This density produced a good mold fill and a firm durable skin surface upon which to bond the flexible foam pads. A specification sheet for this material is included in Appendix A.

4. PROCESS DEVELOPMENT

Phase II foam parts were molded using a Stepan Model 40 foam machine. This is a pour-type machine, capable of a through-put of 40 pounds per minute. The machine uses a high speed rotary mixing head with solvent flush (methylene chloride). Polyol and isocyanate chemicals are continuously recirculated between the mixing head and the material tanks. In-line

heat exchangers maintain proper material temperatures for viscosity control.

Foam materials are mixed in the head at the recommended ratios (1:1 for rigid foam; 1:1.1, polyol/isocyanate for flexible foam) and poured into warm molds. All molds were initially oven heated before pouring. Test pieces were molded at different mold temperatures to optimize density, void elimination, and skinning effects. Optimum mold temperature was established at $110^{\circ}\text{F} \pm 5^{\circ}$ for rigid foam and $100^{\circ}\text{F} \pm 5^{\circ}$ for flexible foam.

Lower mold temperatures produced excessively dense parts and poor mold fill, while higher temperatures produced foam structure breakdown and mold sticking.

All molds were coated with a urethane-based release wax (U.S. Gypsum Epoxical) prior to molding. Each mold was initially coated prior to each pour, but after the molds were "broken in", this was reduced to coating prior to every third pour.

Parts were typically demolded 15 minutes after pouring. Shorter demold times produced surface tearing, cell collapse, and permanent part distortion. Longer demold times had no appreciable effect. All flexible foam parts were compressed after demold to open cells and prevent collapse and distortion of the parts.

During flexible molding operations, a dark green general purpose pigment was mixed with the polyol in an attempt to achieve a "field green" finished part (the normal color of the cured foam is buff, or pale yellow.) This pigment is typically used to tint polyester and epoxy resins. The styrenes in the pigment had an adverse effect on the polyol, resulting in extreme part shrinkage and loss of flexibility. The attempt to color the foam was abandoned until Phase IV, when a different type of pigment was investigated.

5. TEST SPECIMEN FABRICATION

Four sets of foam parts, including four encapsulated CRT's, were fabricated during this phase. In addition, a dummy CRT, constructed of wood and aluminum was built and encapsulated. The dummy CRT was ballasted to duplicate the weight and inertias of an actual CRT. It contained a cavity located near the center of gravity in which a three-axis accelerometer could be mounted.

Flexible foam parts were bonded to the dummy CRT block and one "live" CRT block, using epoxy adhesive, for drop tests. The "live" CRT, with foam parts installed, along with the metal drop case and electronic display generator, are shown in Figure 8.

6. PRELIMINARY DROP TESTING

A simple drop rig, shown in Figure 9, was designed and built to accurately support and release the test specimen from a prescribed height and orientation, using a horizontal pendulum technique. All initial drop tests were performed with the dummy CRT mounted in the drop case.

The accelerometer in the dummy CRT was connected through charge amplifiers to low-gain linear amplifiers, and then to a three axis strip recorder. The recorder was calibrated to measure accelerations along three orthogonal axes, oriented parallel to the three principal axes of the test case.

A series of drops (forty in all) was initiated, beginning with a one foot drop height and progressing up to four foot drops. Drops were made on various faces, edges and corners. Because of various symmetries in the specimen, not all twenty-six aspects were investigated.

The resulting recorder plots showing X, Y, and Z axis accelerations versus time, display classical damped spring-mass system behavior. As was expected, the largest accelerations were recorded along those axes in which the initial impact force vector due to drop had components.

In every case, the vibration due to the drop was damped out to less than 5% of maximum in less than 100 milliseconds. A typical recorder trace of four foot drop onto a face of the case is shown in Figure 10. This drop shows a peak acceleration of slightly more than 80 g's. This is significantly more than the 50 g's design goal.

On the other hand, a typical drop onto a corner is shown in Figure 11. (The scales are expanded relative to the previous figure). The peak acceleration in this drop is only 30 g's. This is consistent with the idea discussed in the Phase I section. That is, a drop onto a side or end presents the maximum flexible foam surface area normal to the drop axis and therefore, a maximum resisting reaction to the inertia forces of the CRT mass. A corner drop aspect, which presents the minimum projected foam area normal to the drop axis, results in less reaction, more foam deflection and consequently, less deceleration load on the CRT.

One concern during the design of the foam suspension system was that by designing for 50 "g" forces in a side or end drop, too little projected area would be available for corner drops and therefore, the CRT would "bottom out" producing very high loads. In none of the corner drops was there evidence of "bottoming." However, peak accelerations of 80 g's were recorded during several side drops. Therefore, a reduction in foam pad cross-sectional area was indicated.

The dummy CRT unit was reconfigured with a new set of foam pads each with 50% of the surface area of the original pads. Selected portions of the previous drop schedule were repeated at two and four foot drop heights. The results indicated that in the case of side and end drops, the peak g's were reduced to 36 or less. Corner drops produced measured g's of 20 or less, again, with no evidence of "bottoming out."

Drops from a height of six feet, the maximum capability of the drop rig, produced accelerations of less than 60 g's.

On the basis of these tests, it was decided to proceed with the "live" CRT, using the reduced area foam system and starting immediately from the four foot drop height. Accordingly, a sequence of four foot drops on both ends, top, one side and two diagonally opposite corners was completed using the "live" CRT. After each drop, the case cover was removed, the unit was inspected for damage and an electronic checkout package was connected to the CRT. The crosshatch test pattern generated was checked against previously applied targets on the face of the tube. In every case, there was no measurable distortion or shifting of the display.

Since no damage had resulted from any of the drops, it was decided to reconfigure the CRT with the original full size foam pads and repeat the drop sequence. This would subject the tube to an acceleration spectrum with peak values as high as 80 g's. These tests again resulted in no measurable damage to the tube or display.

The following conclusions were derived from the tests:

1. On the basis of one sample, either the original or the reduced area foam configurations were acceptable from a shock point of view.
2. The selected CPT was able to withstand at least 80 g's without damage.
3. It may be possible with further testing to reduce the overall package size by reducing both the foam thickness and area.
4. Since the natural frequency of the system is reduced by reducing the area of the foam pads, the second foam test configuration (50% area reduction) is preferred from a vibration point of view.

The successful completion of preliminary testing led to Phase III testing by an independent laboratory.

VI. PHASE III

Phase III was divided into two parts: independent testing and video terminal preliminary design.

1. Testing

The particular tests to be performed by an independent laboratory were associated with temperature, fungus, vibration and shock. The applicable sections of MIL-STD-810C are: 501.1, high temperature; 502.1, low temperature; 503.1, temperature shock; 508.1, fungus; 514.2, vibration and bounce loose cargo; and 516.2, shock drop.

The planned test sequence would subject one CRT package, installed in the "drop box", to the complete spectrum of vibration and shock as defined in MIL-STD-810C. The second CRT package would first be subjected to the high and low temperature, temperature shock, and fungus portions of MIL-STD-810C. It would then be installed in the metal box and subjected to the identical vibration and shock tests that the first CRT package received.

The first CRT package would thus function as a "control" to determine whether or not the temperature and fungus tests had a deteriorating effect on the foam materials sufficient to cause failure during the vibration or shock tests.

The test plan, as supplied to the testing laboratory, was included in the Phase II report. This plan defined the sequence of tests and the required checks on CRT operation to be performed by the tester. An electronic test pattern generator was supplied to the testing laboratory. The pattern generator, when connected to the CRT and deflection yoke caused a cross-hatch pattern to be displayed on the screen. A series of targets were marked on the screen at the intersection of crosshatch lines. Any shift in pattern as a result of testing could then easily be determined.

Two encapsulated CRT's, with flexible foam pads installed, along with the metal drop case and an electronic test package, were sent to an independent testing laboratory (Detroit Testing Laboratory, Oak Park, Michigan).

The complete test report, prepared by Detroit Testing Laboratory, is enclosed in Appendix B. The results of all tests were positive. That is, after each test, there was no damage to the tube, deflection yoke, or surrounding urethane foam support system. Furthermore, there was no significant shift or distortion of the displayed crosshatch pattern except for small anomalies which were attributed to an instability in the pattern generator.

That these shifts were due to the pattern generator and not due to shifting or damage to the internal CRT components was verified by using the

second CRT as a "control." In other words, when some display anomaly was noted after a particular test, the pattern generator was disconnected from that CRT and reconnected to the other CRT. In every case, the pattern anomaly appeared on the second CRT as well.

These anomalies occurred after only one vibration test and two drop aspects. They were verified as being pattern generator related as discussed and were corrected by adjustment of the pattern generator controls.

There were some slight pattern shifts ($+ 1/16"$, $+ 1/8"$) after some tests but because there was no pattern distortion, no variation in brightness or focus, and because the shifts were not progressive, they were judged to be inconsequential and were probably pattern generator related.

During these tests on two different CRT specimens, conducted by an independent laboratory, and the tests performed by Centro Corporation on a third specimen, no damage or defect was observed. On this basis, it was concluded that the design of the protection system was sound and could be incorporated into a complete video terminal.

2. PRELIMINARY TERMINAL DESIGN

The successful demonstration of a protection system for a commercial grade CRT confirmed the feasibility of packaging delicate operational electronic components with simple, low-cost methods within a container. The next step was to define a representative video terminal which would incorporate the CRT protection system and extend that system to the protection of other electronic components.

This included several separate tasks, broken down as follows:

- a. Definition of hardware to be packaged, including weight, volume and operating requirements.
- b. Definition of mechanical packaging, mounting and inter-connection methods.
- c. Definition of requirements for and method of achieving RFI/EMI shielding.
- d. Evaluation and selection of case material(s).
- e. Conceptual design of case including details of hinging, fastening etc., and definition of tooling and manufacturing requirements.

The intent of the preliminary design was to define a terminal using commercial grade hardware and components wherever possible, recognizing that a

definitive production terminal design would substitute military grade components where necessary, and appropriate military standard circuitry and interfaces as required.

The terminal design was to function as a "glass teletype", or device with which to communicate, display alphanumeric text, perform editing functions, and transmit and receive data.

2.1 FUNCTIONAL HARDWARE DEFINITION

The on-board componentry required to produce an operable video terminal can be broken down into four categories: 1. operator interactive components, 2. components necessary to produce a raster scan display, 3. signal and data processing and manipulating components, 4. power supplies.

Among the operator-interactive components is the CRT itself, which is the visual link between the operator and the terminal. The CRT for this application was a 15 inch diagonal measure, rectangular, 90° deflection monochromatic tube with a 4:3 aspect ratio. The tube is a standard commercial unit such as is manufactured by several companies and intended specifically for video monitor use. It is the same tube selected in Phase I.

The tactile component by which the operator communicates with the terminal is the keyboard. The keyboard normally includes the standard QWERTY typewriter format keys (54-63 keys) and may include additional special control keys and a ten key numeric key pad. For environmental protection, the keys, or keyboard, should be sealed to exclude moisture and dirt.

The other operator-interactive components include various video display controls, power connector, and signal connector(s).

Depending on requirements, the video controls may include brightness, contrast, or more extensive controls such as vertical and horizontal hold, etc. These controls are typically panel mounted, shaft driven potentiometers.

The main signal connector is an RS-232 serial port connector. It could be either a 25 pin subminiature D connector which is standard for RS-232, or a MIL-C-26482 type miniature circular connector with attached dust cap. The power connector can be a similar, but smaller, 3-pin connector. Other connectors, such as a printer connector, are possible.

The components necessary to produce a raster scan display include a magnetic deflection yoke, circuits for horizontal and vertical deflection of

the electron beam, various circuits to insure linearity, and signal amplifiers.

The deflection yoke is used to produce the magnetic field necessary to deflect the electron beam and is installed and aligned on the neck of the CRT. It is matched to the CRT neck diameter, deflection angle and screen format.

Deflection circuits are necessary to drive the deflection yoke to achieve the required number of raster lines (525 standard) at the required refresh rate (60 times/second). Circuitry must also be provided which will blank the electron beam during the retrace portion of the sweep cycle.

Linearity circuits are necessary to compensate for the varying angle of the electron beam relative to the tube face as it sweeps the screen. Amplifier circuits are required to raise the video signal to a level sufficient to modulate the electron beam as it sweeps over the tube face.

There are several manufacturers who produce complete circuit boards for these various functions. The functions may be combined in various ways on one or more boards depending on manufacturer.

The signal and data processing components are those circuits which transform binary information from the keyboard and the RS-232 port into the appropriate format for screen display. This includes character generation and also editing features such as formatting, erasing, etc. These circuits also provide a compatible format for transmitting keyboard data through the RS-232 port. Such circuits typically include a microprocessor and various amounts of ROM (Read-Only-Memory) and RAM (Random-Access-Memory).

Power supplies represent the last category of on-board components. These include both high voltage and low voltage supplies. The high voltage supply generates the large potential difference (typically 12-18 KV for monochromatic CRT's) between the CRT screen and cathode necessary to accelerate the electron beam toward the screen. Because of the high potential involved, it was very desirable to isolate and shield this potential from possible operator contact and also remove it from electronic areas subject to possible field maintenance.

The low voltage supplies convert the input voltage, either AC or DC, into the required regulated DC voltage outputs, including the low voltage input to the high voltage power supply.

2.2 PACKAGING AND INTERCONNECTION

The principal packaging requirement is associated with the protection of the CRT. This requirement has been met by the system of urethane foam supports designed and developed in Phases I and II of this effort. In addition to protecting the CRT, the foam also encapsulates and protects the magnetic deflection yoke, which is installed, aligned, and adhesively bonded to the CRT prior to encapsulation.

The required connections to the CRT and deflection yoke include the high voltage anode lead, a deflection yoke, cable and various leads to the pin connections at the end of the CRT neck.

The high voltage power supply is installed in a recess in the rigid foam block which encapsulates the CRT. This location minimizes the high voltage anode lead length and isolates the supply, which is already extensively shielded against corona, from the other video and digital circuits.

The packaging and mounting of the remaining components depends on the overall terminal design concept. Two versions of the video terminal were developed through the preliminary layout stage to define envelopes and design details.

VERSION 1

In Concept Version 1 (Drawing C-5510), all circuit elements except the keyboard and the terminal circuit board are installed in the rigid foam block which encapsulates the CRT.

This concept has the advantage that all of these circuit components are afforded the same shock and vibration isolation and protection that the CRT receives without any additional shock mounting materials required. Accessibility to components for maintenance requires that the complete CRT package must be removed from the case.

VERSION 2

In Concept Version 2 (Drawing C-5536) all circuit elements except the high voltage power supply are installed in a box or tray which is designed to slide in and out of the front of the terminal after the cover is removed. The keyboard is in the front of the tray and moves into user position when the tray is extended. This concept has the advantage that nearly all circuit components are in close proximity to one another, simplifying connections and access for repair.

2.3 SHIELDING REQUIREMENTS

Shielding is required in video terminals because the internal circuits generate timing signals and pulses at rates in excess of a million pulses per second for purposes of timing sequences of events and to carry out control and logic functions. Radio frequency energy associated with these pulses produces emissions that extend well up into the VHF and UHF portion of the radio spectrum. Unless contained or filtered, some of this energy is radiated into space in the form of interference.

Furthermore, because the raster display visible on the CRT screen is refreshed at a rate of 60 times per second, the signal information is repeated over and over at the same rate. Since it is repeated, it can be integrated electronically and "pulled up" out of the random electronic noise environment, making the compromise of sensitive information possible.

Shielding of a computing device is commonly provided by installing the terminal in a metal case, or a metallized plastic case. The metallizing of a plastic case can be accomplished by one of several means, including applying metal foil, metallized interspersions (paint), vacuum metal plating, or arc sprayed metal coating to the inside of the terminal case.

The selected terminal configuration (Version 2) provides shielding by containing the complete electronics package in a metal "drawer" with cables connecting the drawer to the CRT. In addition, the high-voltage power supply is encapsulated in its own metal case.

2.4 CASE MATERIAL SELECTION

Plastic materials have advantages over metal for case construction because of material and fabrication costs. Also, unlike metals of similar wall thickness and reasonable weight, certain plastics are able to withstand substantial impacts without suffering permanent denting or other damage.

Plastics are characterized as either thermoset or thermoplastic in nature. Cases of thermoset material, typically polyester/fiberglass or epoxy/fiberglass, are quite common in the military inventory and have proven to be rugged and fairly durable. However, the materials used in these cases do not always exhibit particularly good impact resistance. Some thermoplastics possess exceptional impact resistance, particularly at moderate to high temperatures, and they can be formed by a variety of low-cost processes, including injection molding, blow molding, rotational molding and thermoforming.

Thermoforming is particularly attractive because simple, low-cost tools can be used and the tools, which can be constructed of wood for prototype work, can be easily modified. This was especially important for this

program because it was expected that even with careful design for impact resistance, some actual component testing and modification would be desirable and likely. The complex physical phenomena involved in impact loading make accurate analytical prediction of case behavior impossible.

The accessibility of subcontracted thermoforming services, combined with the low cost of required tools, influenced the selection of the case forming process in favor of this method.

Certain material properties are important when selecting a thermoplastic material for case fabrication. The material must have good tensile and flexural strength and modulus. It must have a high percentage of elongation before failure (not be brittle.) It must have good impact resistance (characterized by high Izod notch or other impact test numbers.) Finally, it must have the ability to withstand high temperatures (high deflection temperature) and not become brittle at low temperature.

A review of plastics properties and trade literature resulted in the selection of three (3) candidate materials for terminal cases. These were relatively common and readily available materials. Other materials were found which had equal or superior properties in certain categories, but were judged deficient in other categories and/or they were not commonly available or were expensive. Table I lists the selected materials, along with some important properties.

High-impact ABS (Acrylonitrile-Butadiene-Styrene) is a very common thermoplastic. It is used in many applications which require durability such as power tool housings and toys. Special formulations are available which retain high-impact properties at low temperatures. It is the least expensive of the three selected materials. It must be protected by paint or other coating against prolonged ultra-violet exposure which will eventually cause a reduction in properties.

Polycarbonate can be formed into clear sheets and is commonly used as a high impact glazing material. It is also being used in business machines and in automobile instrument panels, trim and bumpers. It is sensitive to ultra-violet light and tends to become brittle after exposure. It is more commonly available in transparent rather than opaque grades.

Acrylic/polyvinyl-chloride alloy is a thermoplastic developed for very good toughness, impact strength and wear resistance. It will not sustain combustion. It retains good toughness and impact strength even at low temperatures. It is its toughness and resistance to abrasion which principally distinguishes this alloy from ABS or polycarbonate. Furthermore, it has good resistance to ultra-violet light.

Because of its inherent toughness, acrylic-PVC alloy was selected as the material candidate to be evaluated for terminal use.

VII. PHASE IV

The CRT protection system was designed and successfully tested and all of the other major elements necessary to construct a complete video terminal were defined in the preceding phases of the program. During Phase IV, specific electronic components were selected and purchased, the terminal configuration was finalized, tooling was designed and constructed, parts were fabricated, and a complete video terminal was built and shock tested.

As was discussed in the Phase III portion of this report, two versions of the terminal were defined. After a review with the Army Project Engineer, Version 2, with the sliding drawer, was selected as the configuration to be fabricated.

Because of the success demonstrated in protecting the CRT, it was concluded that this technique could be adapted to the protection of the slide-out drawer containing the keyboard and most of the electronics.

To take maximum advantage of the development work which produced the CRT protection system, the electronics drawer in the final design was isolated from the CRT within the case by a partition. Thus the CRT isolation system with some refinement, could be used as previously tested and the protection system for the drawer could be developed as a separate problem. The partition eliminates interaction between CRT and drawer loads at the expense of some increase in package volume.

The critical loading imposed on either the CRT or the drawer is shock loading due to the MIL-STD-810C 48 inch drop test. The maximum deceleration limit selected for the CRT, based upon shipping industry guidelines, was 50 g's. During the preceding phases, one CRT was successfully tested up to 80 g's; however 50 g's was retained as a conservative design objective. The deceleration limit selected for the drawer was 80 g's, based upon a shipping industry guideline for "moderately delicate electronic equipment."*

In terms of energy absorbing capability of flexible urethane foam, 50 g's corresponds to a theoretical deceleration distance of 2.0 inches and 80 g's corresponds to 1.3 inches.

In addition to developing the molded urethane foam protection system, this phase included the development of a survivable external case. A thermoflexible plastic material was selected for case fabrication for reasons of resistance to damage and manufacturing cost. The goal was for the case to remain intact without cracking through all environmental testing.

The ruggedized video terminal design that evolved from the various requirements and the selection of components is shown in sectional view in drawing C-5785. This design incorporates a sliding metal drawer containing the

* Modern Packaging Encyclopedia

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keyboard and electronics. The drawer and the CRT block are mounted in independent suspension systems separated by a molded partition.

1. CRT PROTECTION

The CRT protection system is shown in the upper part of Figure 12. It consists of a rigid molded urethane foam block which completely and permanently encapsulates the CRT and deflection yoke except for the face of the tube and the filament and socket portion of the CRT neck, a flexible molded urethane frame, or bezel around the face of the CRT, and four flexible urethane corner blocks at the rear of the rigid foam block. The flexible foam parts are attached to the rigid foam with RTV. There is a notch in the top of the bezel foam which is a ventilation slot to assist in eliminating heat generated by the CRT filament and the high voltage supply.

There is a cavity visible in the top of the rigid foam block in Figure 12. A similar cavity in the bottom of the block contains the installed high voltage power supply. The high voltage anode cable is encapsulated in the rigid foam, except for a short lead which connects the the H-V power supply.

The CRT protection system is functionally identical to the system developed in an earlier phase of the program. It provided a nominal isolation distance between the rigid block and the case of about 2.75 inches, which permits a 2.0 inch compression plus volume for the compressed foam. The corners of the blocks are molded with radii as required to fit within the plastic case.

2. DRAWER PROTECTION

The drawer suspension system consists of two flexible molded urethane "collars" which are installed in the front and back of the case below the partition, and which contain thin sheet aluminum spot welded frames. Standard commercial electronic drawer slide mechanisms are attached to these frames. The drawer slide rails thus maintain the collar spacing within the case. The aluminum frames are sized to clear the envelope of the drawer slightly, so that when a shock load is imposed, the frames deflect only slightly before they contact the drawer which then transmits its load directly into the urethane foam without damaging either the frames or the slide mechanism.

Several cavities are molded into the collars in selected locations to optimize the compression area of the foam for the design weight of the drawer. The minimum isolation distance between the drawer and the case is 1.8 inches, which permits a 1.3 inch compression of the foam.

All of the urethane foam parts including the rigid foam encapsulating the CRT and the contoured foam filler for the lid are shown in Figure 13.

3. CASE DESIGN

The case was designed so that all parts could be thermoformed using simple tools. A previous screening of thermoplastic sheet materials had narrowed the choice of plastics to polycarbonate, acrylonite-butadiene-styrene (ABS), and acrylic/polyvinyl-chloride alloy. Prior to actual forming, polycarbonate was eliminated from the evaluation primarily because of the necessity for extensive drying of the material prior to forming (no drying oven was available at the thermoforming site.)

It was planned that the case would be formed in a single piece if possible. Accordingly, a forming plug with the interior dimensions of the case but without the various stiffening ribs and other pockets was constructed to quickly evaluate the feasibility of single piece forming. Initial corner and edge radii were 1 inch. Because of the draw ratio (ratio of depth of draw to length and width) a "billow forming" technique was used. In this technique, the heated plastic sheet is first "billowed" into a bubble. The forming plug is then rammed into the bubble while the billowing air pressure is simultaneously reduced. This effectively turns the bubble inside out. A vacuum is then pulled at the forming plug, pulling the plastic sheet material against the plug. This technique theoretically minimizes variations in wall thickness. In addition, the thickest commercially available sheet stock (.250 inch) was used. This would produce a part with a nominal wall thickness of .130 inches.

4. CASE CONSTRUCTION

Significant problems were encountered when the case forming process was attempted. Severe tearing of the sheet material occurred, both with ABS and acrylic/PVC. Wall thicknesses varied from nearly the full .250 inch stock size to under .090 inch. Furthermore, in the case of the acrylic/PVC material, a recurring band of "bubbles" and depressions appeared in each sheet as it was heated. The parts made at this time were entirely unsatisfactory.

Accordingly, a decision was made to form the case in two halves and to incorporate a measure of "slip-forming", using a larger sheet size, into the process. While the forming plug was being modified, samples of the acrylic/PVC material were supplied to the manufacturer (Rohm and Haas) and to the Army Materials Project Engineer for evaluation. It was determined that the material was defective, apparently due to a problem with the extrusion dies. New material was ordered. During this period, some dead weight tests were conducted on the defective case parts and it was decided that the edge radii would be increased to 1.5 inches and the rear corner

radii would be increased to 2.0 inches to better distribute impact loads.

It was decided at this time to limit all subsequent case forming to acrylic/PVC, for reasons of program cost.

In subsequent forming operations on new acrylic/PVC material no problems with tearing or bubbles were encountered. The first parts formed had a variation in wall thickness of between .100 and .200 inches. Subsequent adjustments to oven heat distribution and the use of oven shading, combined with adjustments in billow height and "slip-ring" shape reduced the variations to between .120 and .180 inches.

Some "webbing" occurred in the corners of the formed parts in the areas that would eventually form the case lap joint. This resulted in a crack in the material during one drop test. In an optimized forming process, this webbing would be eliminated by adjusting the slip ring to plug clearance.

Besides the case halves, other thermoformed parts included the lid, partition, and fascia panel. The lid, like the case halves, was formed over a male plug, but because of the shallow depth of draw, billow forming was not necessary. Conventional vacuum-assisted drape forming was used. The partition and the fascia were vacuum formed into female molds. This was done because the outside dimensions of these parts required accurate control to mate with the inside dimensions of the case.

Material stock thicknesses used were 3/16 inch for the lid and 1/8 inch for the fascia and partition. A complete set of thermoformed acrylic/PVC case parts is shown in Figure 14.

It is probable that a case could successfully be formed in one piece, at some expense in average wall thickness, based upon the results of subsequent forming operations. This was not attempted due to limitations of program cost.

5. FOAM MOLDING

The CRT and deflection yoke were encapsulated in the same rigid urethane foam used in Phase II. All foam mixing in this phase was performed using an Admiral Model 40 foam machine. The tube encapsulation mold was redesigned somewhat from Phase II. A molded flexible synthetic gasket was installed in the bottom of the mold. With the face of the tube down in the mold, the gasket extended up the perimeter of the tube face to form a step in the rigid foam. The complete encapsulated CRT unit weighed about 17 lbs of which about 3 lbs was foam.

It was intended to pigment the flexible foam to match the color of the

case (light beige). However, the pigment selected did not produce enough color saturation to overcome the basic yellow color of the unpigmented foam, so this attempt was abandoned.

6. DRAWER CONSTRUCTION

The drawer and drawer frames, shown in Figure 15 are aluminum weldments, constructed of 3003-H14 sheet stock. The bottom panel of the drawer is removable for access to the electronics. Cooling vent holes are provided in the forward portion of the bottom panel.

7. ELECTRONICS

The electronic package was developed to provide an alphanumeric display capability for testing and demonstration. All elements of the package were purchased from commercial stock items. The complete interconnection diagram is shown in Figure 16.

The various circuits were selected for availability, cost and applicability to the previously selected 15 inch CRT. They were not intended to be an optimized design but would help to identify potential problems and design considerations when adapted to the requirements of severe environmental testing.

All leads from the drawer to the CRT and high voltage supply are contained in a single twelve wire cable. The complete electronic system, except for the CRT, is shown in Figure 17. The high voltage supply, which is the black cube on the right side of Figure 17, is installed in the CRT foam block. All other electronics are mounted in the drawer.

Figure 18 is a bottom view of the drawer with electronics installed. The keyboard panel is at the top of the figure. The OEM video board used in this assembly was obviously not optimized for rough handling as it has many upright and unsupported components. Large components such as electrolytic capacitors were bonded to the PC board with RTV prior to installation in the drawer.

8. CASE ASSEMBLY

The two-piece case was assembled around the various foam parts for simplicity. Figure 19 shows the lower case half with the drawer foam collars, aluminum frames and slides, and the partition in place. The joint between the partition and the case, as well as the lap joint between the case halves was adhesively bonded using tetrahydrofuran (THF) solvent as the adhesive. Other common solvents have little or no effect on the case

material. Aluminum rivets were used to fixture the parts together as the THF was applied to the edge of the joint and allowed to penetrate between the parts. Throughout the subsequent drop tests, no problems were experienced with any of these adhesive joints.

The fascia panel was installed using rivets only. The fascia is removable by drilling out the rivets so that the CRT module can be removed (see Phase V). The complete unit with drawer extended is shown in Figure 20. The complete unit with the protective cover is shown in Figure 21. This is the transport configuration.

9. PRELIMINARY TESTING

A thermal test was performed to determine the heat rejection capability of the tube filament area of the encapsulated CRT. This test consisted of several 8-hour periods of operating the display and examining the tube and foam in the vicinity of the filament for excessive heat or damage. After operating a tube for extended periods, it was apparent that so little heat was present in this area that neither the tube nor the foam was likely to be damaged.

A series of high temperature tests were conducted on the case materials. Formed sections of ABS and acrylic/PVC material were subjected to oven heating at various increasing temperatures until relaxation of the material was experienced. In the case of the ABS, this occurred at approximately 250°F while the acrylic PVC began to deform at about 200°F. This is consistent with the published deflection temperature data recommended forming temperatures for these materials.

10. DROP TESTS

Two terminals were completed for preliminary drop testing. One unit contained a dummy CRT with a three-axis accelerometer mounted on the tube C.G., and a drawer, with dummy mass elements mounted to simulate the various electronic circuits and a three-axis accelerometer mounted on the drawer C.G. The second unit contained the complete electronics package.

A series of 26 drops with the instrumented terminal established that the target acceleration levels of 50 g's for the CRT and 30 g's for the drawer were not exceeded except for drops on the front face of the terminal, when the acceleration experienced by the CRT was over 60 g's. A modification to the flexible foam in the case lid, reducing the bearing area against the face of the CRT, lowered the acceleration level to about 40 g's.

During the dummy drops, a 3-inch crack was found in the case, originating within the overlap joint at one edge. It was determined that this crack

was a continuation of a discontinuity formed when "webs" in the case corners were ground off prior to assembly. The crack was stop drilled and no further cracks appeared on either the dummy or the "live" terminal case.

In all subsequent drops with the dummy and the "live" terminal, external damage was confined to denting of the case corners. It was found that applications of heat from a heat gun would restore the corner dents. Internal damage was limited to some slight shifting of the foam parts within the case and some evidence of stress "whitening" of the fascia panel due to flexing. There were also two failures associated with the electronics. In one case, a tuning coil form on the video board broke off. The coil form, which was made of a material similar to a soda straw failed because of the shock load imposed on the cantilevered coil and slug. The coil was replaced and a reinforcing sleeve was bonded over the coil form. The second failure was an intermittent contact within a connector on the video board. This was reconnected and the cable leads were potted in RTV.

These relatively minor damage incidents could not be attributed to a failure in the basic design of the terminal mounting system. Accordingly, it was decided that with only detail changes in the construction of the case and a refined case forming process to eliminate "webbing", the Phase V portion of the program, including the complete environmental testing of one terminal and the assembly of three others, would be initiated.

VIII. PHASE V

During Phase V, four ruggedized video terminals were assembled using the tools and techniques developed in the preceding phases. In addition, one of these terminals was subjected to complete environmental testing by an independent laboratory.

The environmental tests were the same as those performed on the basic CRT suspension design in Phase III. All tests were performed with the electronics drawer stowed and the cover in place, representing the normal transit condition.

No special protective treatment was applied to any of the commercial electronic modules installed in the test terminal, other than bonding some of the heavier components to the printed circuit boards with RTV. All wire runs were bundled together with plastic tie-wraps. All wires were kept as short as possible. All wire terminations within connectors were encapsulated in RTV.

The sequence of testing was: High Temperature, Low Temperature, Temperature Shock, Vibration-Secured Cargo, Vibration-Loose Cargo, and Shock. The test report in Appendix C summarizes the results.

No problems were experienced during either high or low temperature testing. The unit was required to operate correctly at the conclusion of each temperature soak. A simple test pattern was keyed in on the keyboard and compared to locating marks taped on the screen.

At the conclusion of temperature shock the terminal was inoperative. The problem was traced to the failure of the high voltage power supply. This device is entirely encapsulated in epoxy by the manufacturer and cannot be repaired. After a discussion with the manufacturer, it was determined that the potting compound used was incompatible with the -70°F temperatures experienced in the test. A special version of this power supply is available with low temperature potting compound.

At the conclusion of the temperature shock test, laboratory personnel attempted to remove the terminal cover while the article was still at sub-zero temperature. This caused the cover clasp fitting in the upper right hand corner to break out of the case and caused a crack in the fascia panel in this area.

The failed power supply was replaced and testing continued, using the damaged case. During the secured cargo vibration test, the high voltage power supply and mounting plate came loose within the CRT block, causing a break in the high voltage anode lead.

The terminal was disassembled and examined for the cause of failure. It was determined that the threaded inserts within the high voltage power supply cube failed, causing the power supply to bounce up and down within its cavity in the CRT block. This impact loading caused the threads in the mounting plate inserts in the CRT block to fail.

Because of the physical damage to the test article, a second terminal unit was submitted to the laboratory for testing after modifying the mounting of the high voltage power supply by strapping it to the mounting plate. The complete sequence of testing was repeated to insure that any effects of high or low temperature on the suspension system would be included. However, the high voltage power supply was removed prior to high temperature testing and replaced after the temperature shock test.

All temperature testing and secured cargo vibration testing was completed satisfactorily. At the conclusion of four axes of the loose cargo vibration testing the terminal was inoperative. The failure was traced to a failed solder joint between an unsupported high frequency (small) choke coil and the printed circuit board in one of the low voltage supplies. This was repaired and all similar components were secured to the board with RTV. The remainder of the loose cargo vibration testing was completed successfully.

The shock testing, consisting of 26 drops from 48 inches on each face, edge, and corner of the case was completed without any electrical failure. Mechanical damage consisted of the failure of the riveted connection between the two latches and the case and the spacebar coming adrift from the keyboard. It was determined that the cause of the latch failure was the use of "pop" rivets with insufficient grip length in the latches, causing the head to form within the hole, rather than behind it. The keyboard spacebar, which has a boss which is a press fit in its switching plunger, came loose because of pressure exerted against the spacebar by the lid foam during a drop on the front face of the case.

External damage to the case, aside from scratches and the loss of two latches, consisted of small dents in some of the corners. The largest dent could be covered with a half dollar and was approximately 1/4 inch deep. There was no evidence of cracking or failure of bonded joints. No foam was torn or permanently displaced.

The unit which completed the entire test cycle was left with all external damage unrepaired.

A fungus test was performed on a specimen of a thermoformed case. At the conclusion of the test, no fungal material was observed on the specimen.

IX. CONCLUSIONS

This program has successfully demonstrated that standard commercial CRT's and electronics can be packaged and protected with minimal special adaptation so that they may be deployed in a military environment. In addition, the protection materials - rigid and flexible molded urethane - can be inexpensively fabricated for custom applications and they will continue to give good protection when subjected to a variety of environmental extremes.

It is further possible to fabricate a protective case, using low-cost thermoforming techniques, which will survive severe impact and shock at room temperature, although the shock protection capability of these materials at very low temperatures was not demonstrated.

The electronic circuit boards and modules used in this program were typically selected based on electronic requirements, price, and availability. In some cases, it was possible to select elements with environmental specifications appropriate to the tests imposed in the program. In other cases, these specifications were unavailable. Features, or lack of same on the latter electronic elements, led to the failures experienced during testing.

Failures associated with testing, although unanticipated, were nevertheless, minor and were typically the result of commercial practices in electronic circuit fabrication not being up to the more severe Military Standards tests. The most significant design defect from the point of view of the military environment was the rather widespread use of unsupported, relatively massive components on circuit boards, such as coils and large capacitors. Several simple modifications were identified or performed which would undoubtedly permit a terminal to complete the full series of tests without failure.

The techniques and materials investigated during this program lend themselves to straightforward adaptation to other protective functions and the use of other low-cost commercial electronics, suitably protected, may be possible in the military environment.

The adaptation of commercial electronic components to the military environment through the use of relatively simple technology and modification processes has been demonstrated through the testing of a representative video terminal. The methods used are straightforward and utilize readily available commercial materials and manufacturing processes which do not demand excessive and expensive controls. The next step is to extend the technology to a specific application with well-defined electronic functional and operating requirements.

X. FIGURES



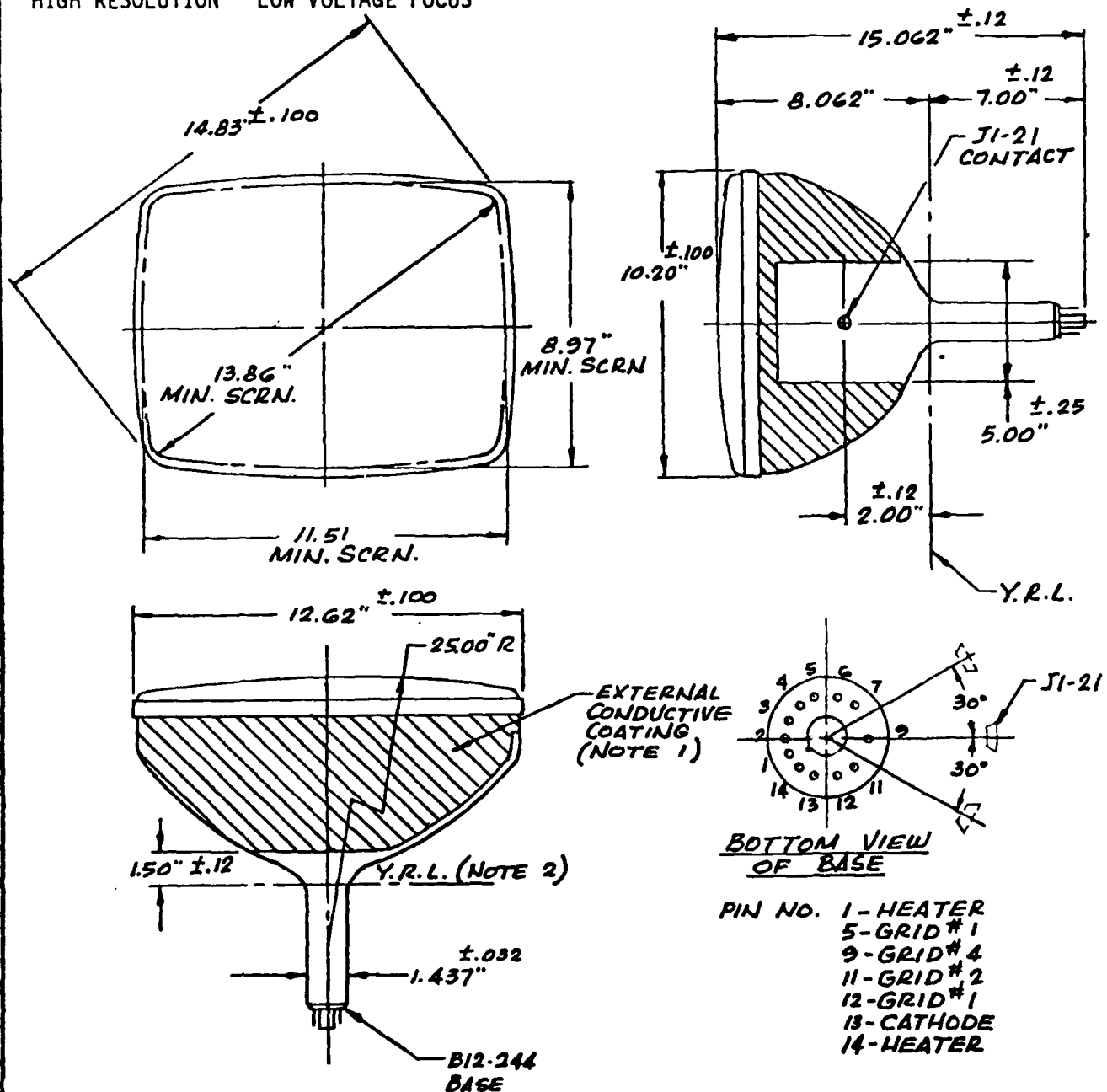
CLINTON ELECTRONICS CORPORATION

6701 Clinton Rd.
Rockford, Illinois 61111
815-633-1444
Telex 257-484

CATHODE RAY TUBE TYPE: CE551-M15P4

15" DIAGONAL, 90° MAGNETIC DEFLECTION, 1 7/16" DIAMETER NECK

HIGH RESOLUTION LOW VOLTAGE FOCUS



REV	DATE	DWG	APP	SHEET
FIGURE 1				1 of 10

46 1512

K-E 10 X 10 TO THE CENTIMETER 10 X 25 CM
KEUFFEL & ESSER CO. MADE IN U.S.A.

DYN 4/2/61

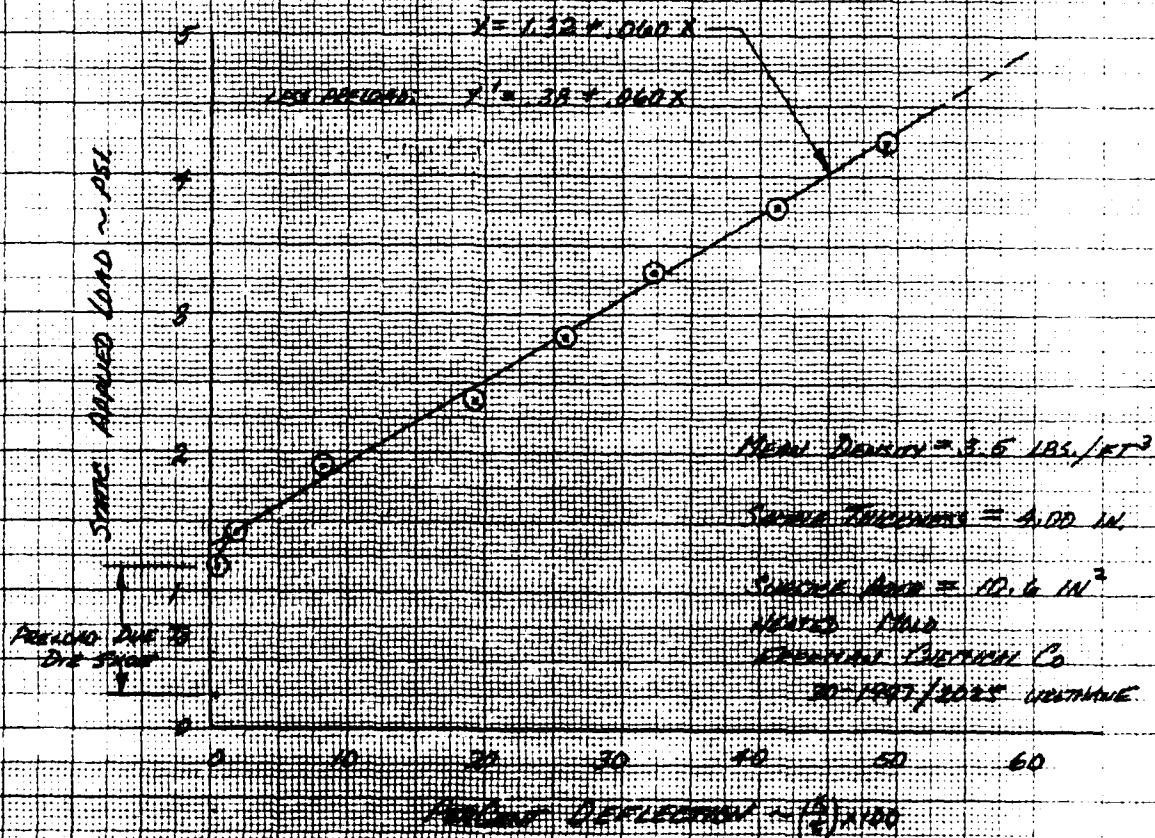
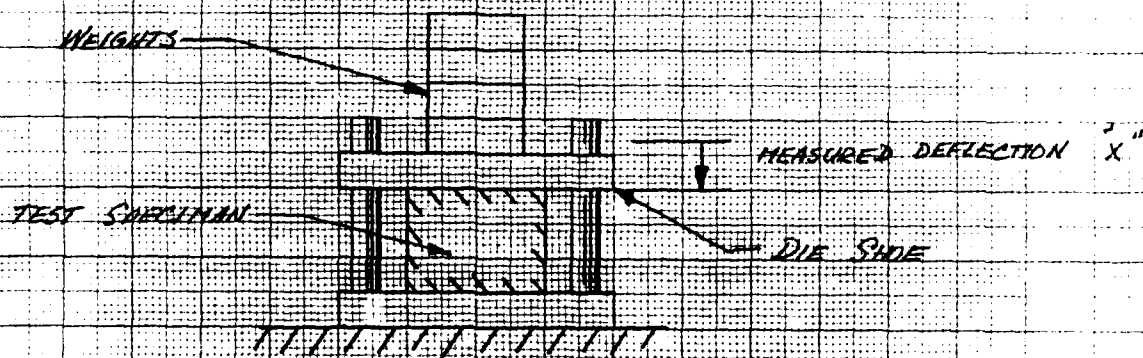
FLEXIBLE FOAM LOAD VS DEFLECTION TEST

Figure 2

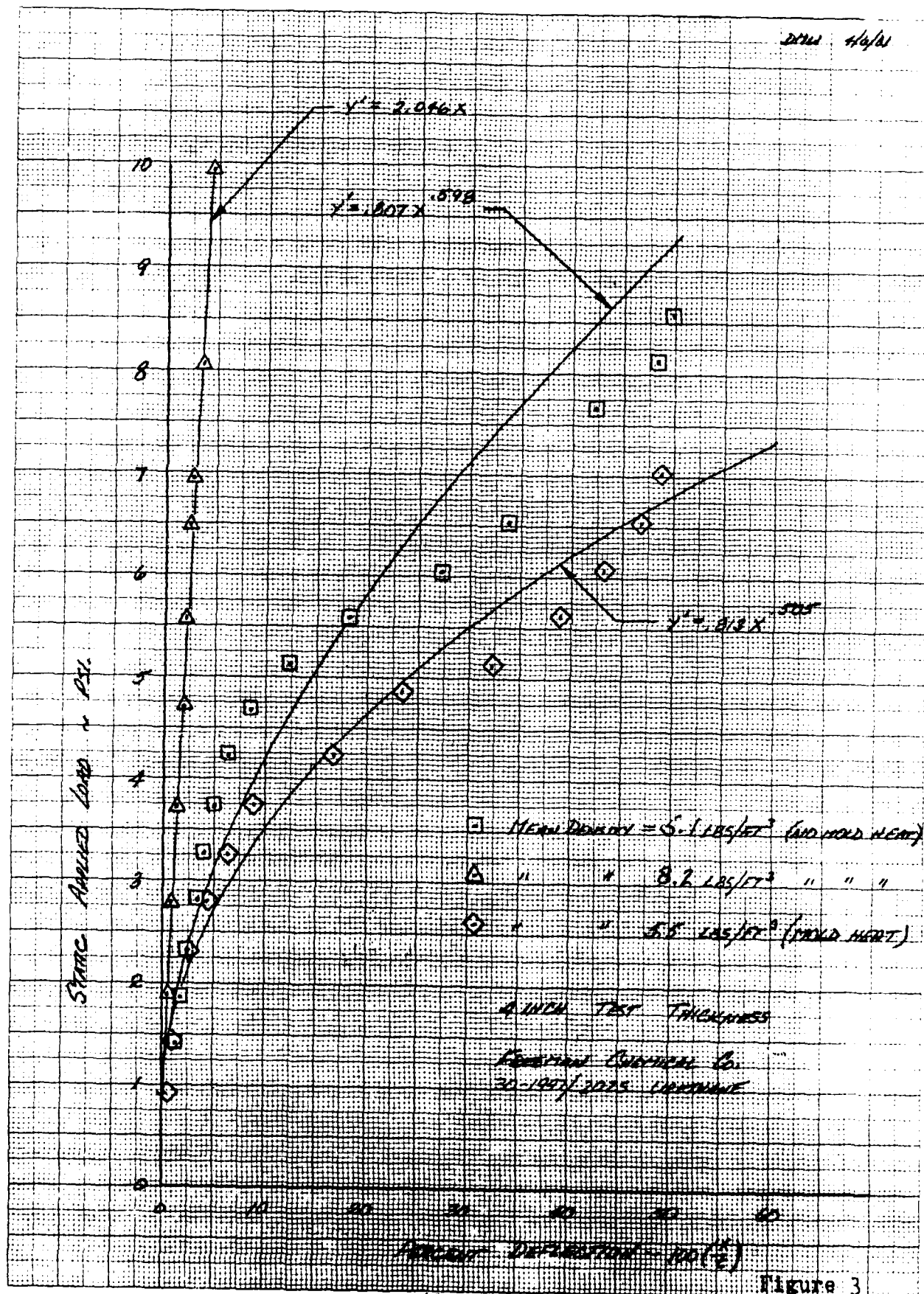


Figure 3

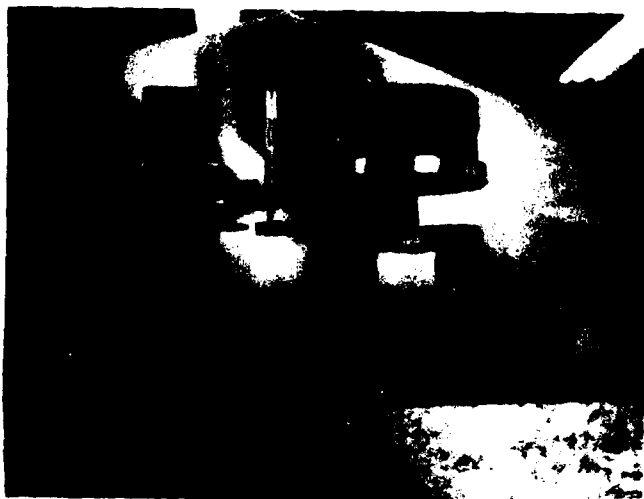


FIGURE 4

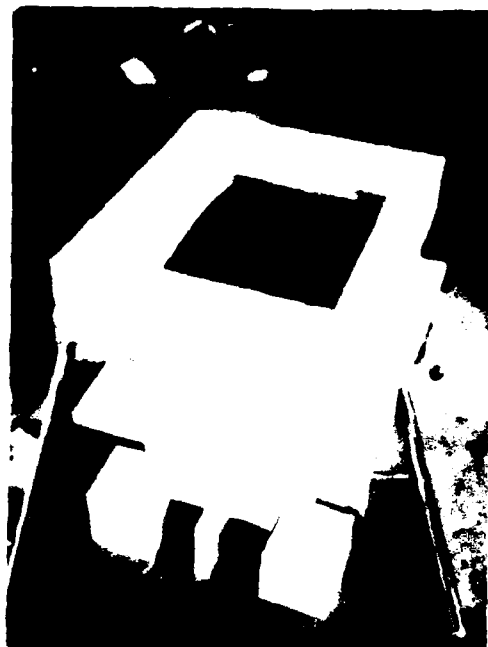


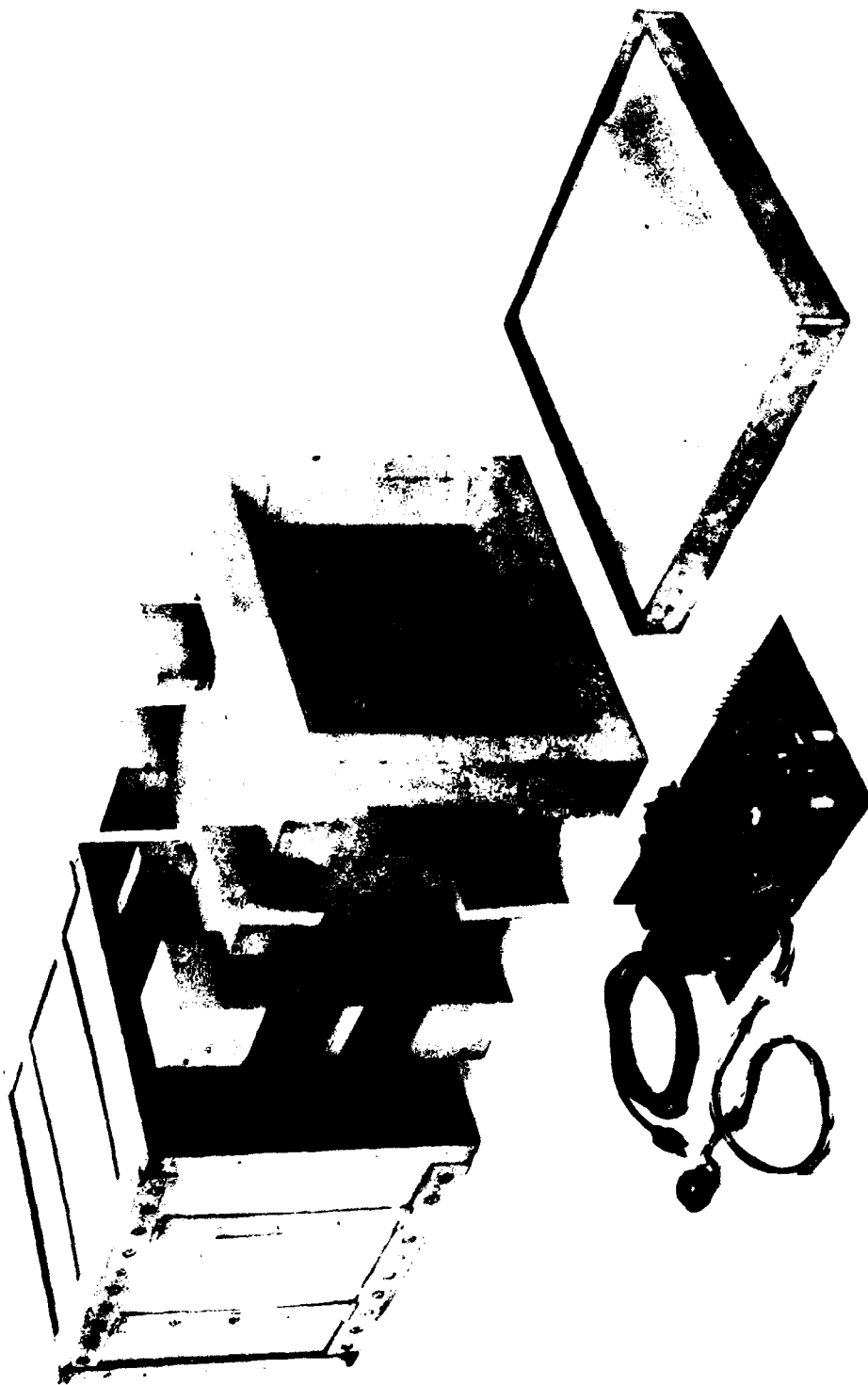
FIGURE 5



FIGURE 6



FIGURE 7



"EXPLODED" PHOTOGRAPH OF THE CRT,
FOAM PACKAGE, "DROP BOX" AND TEST PATTERN GENERATOR

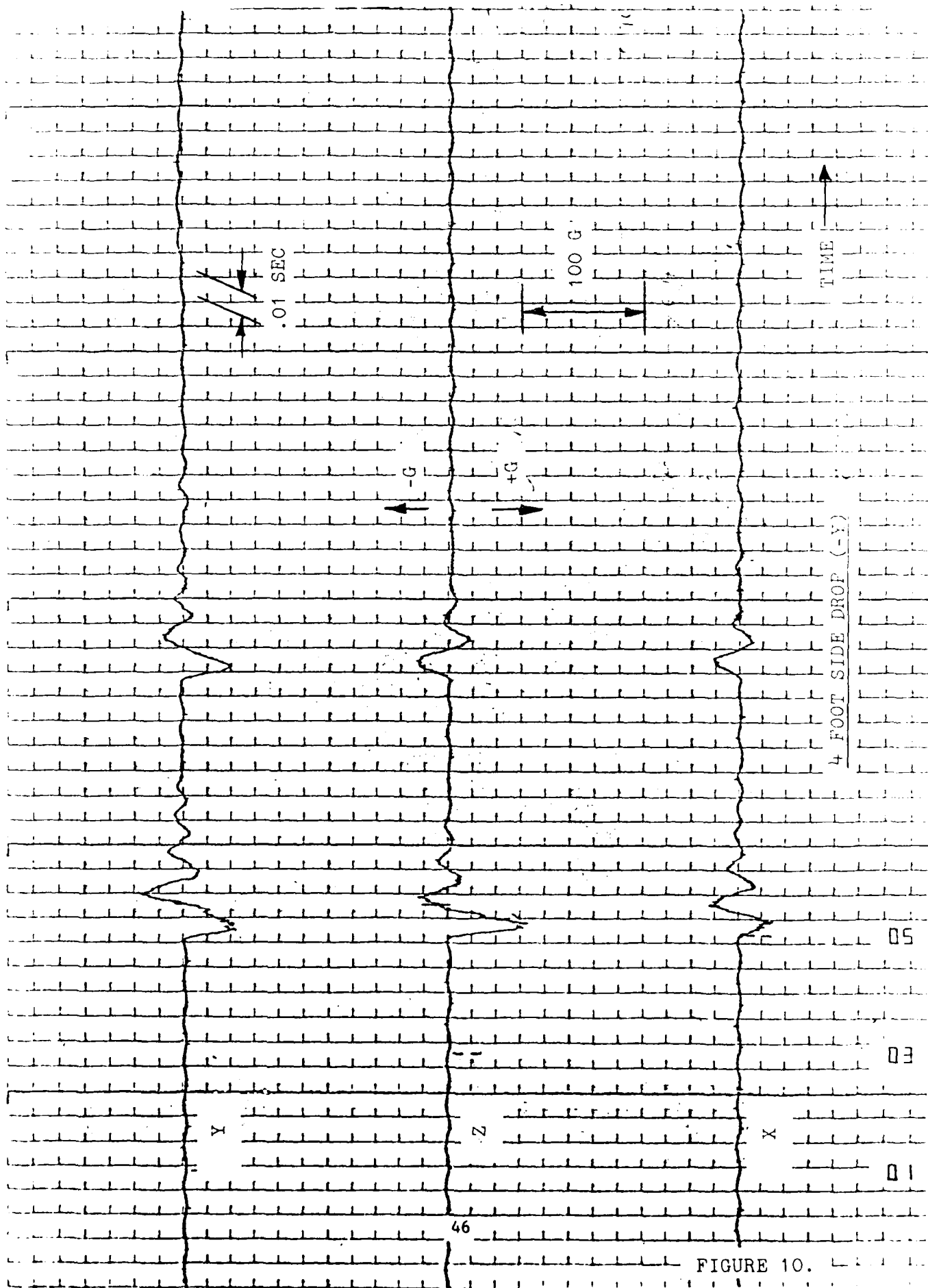
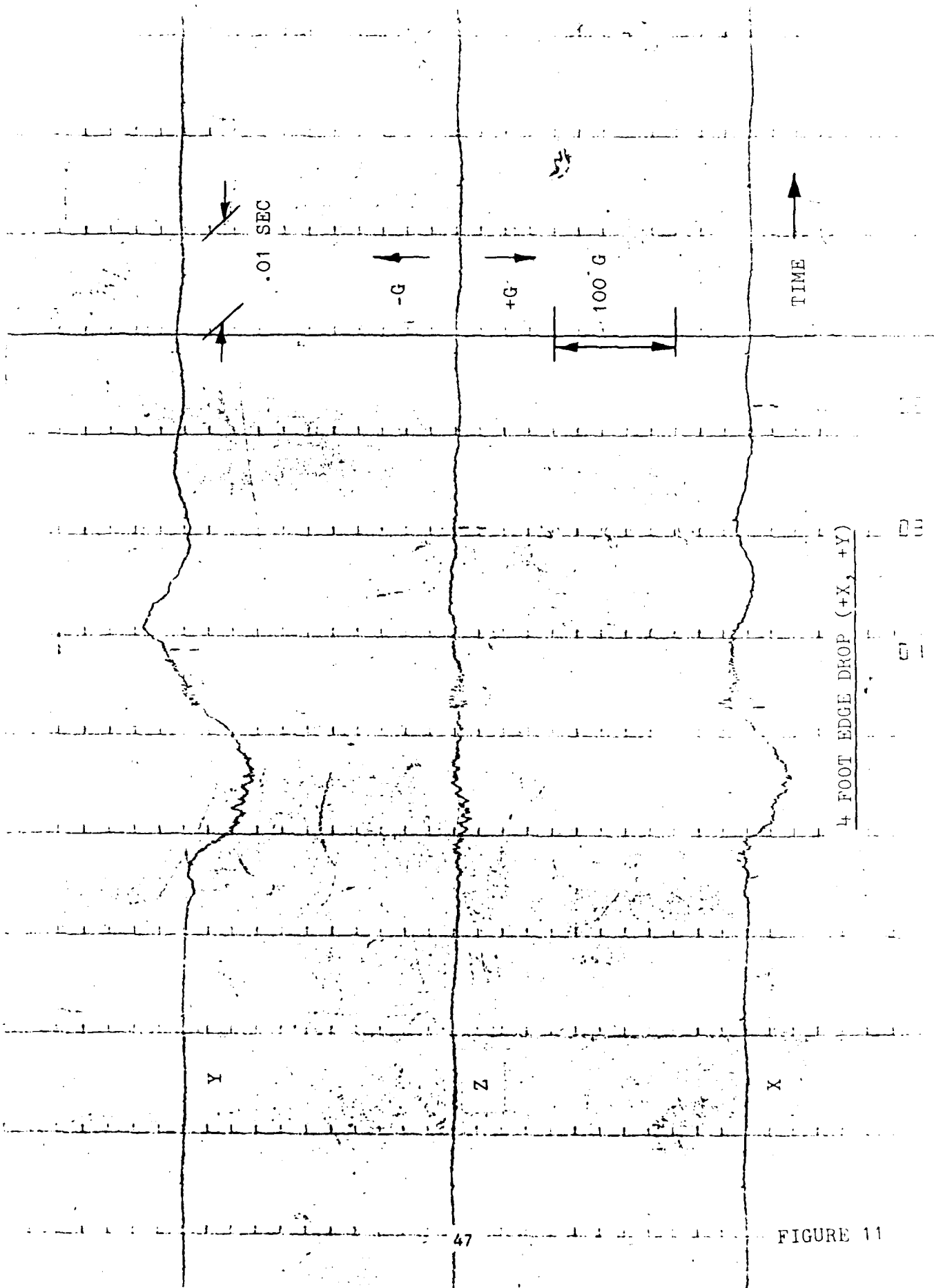


FIGURE 10.



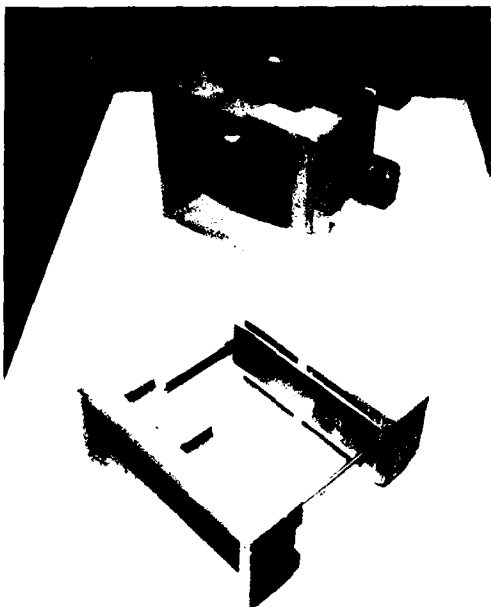


FIGURE 12



FIGURE 13

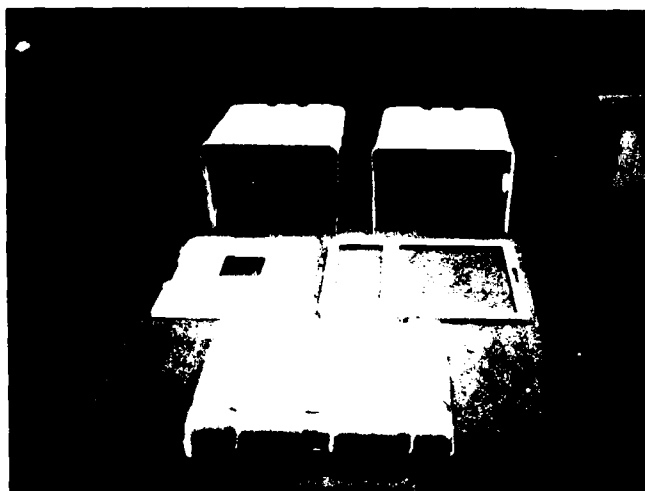


FIGURE 14

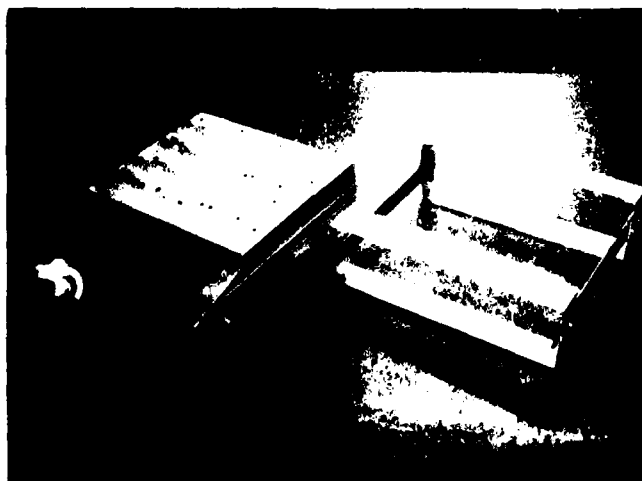


FIGURE 15



FIGURE 17

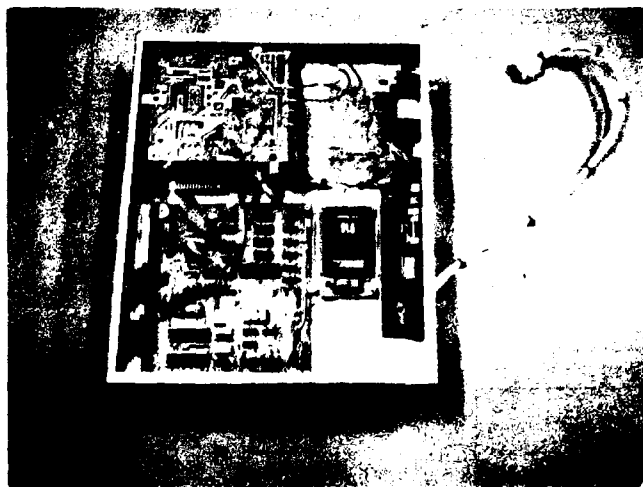


FIGURE 18



FIGURE 19

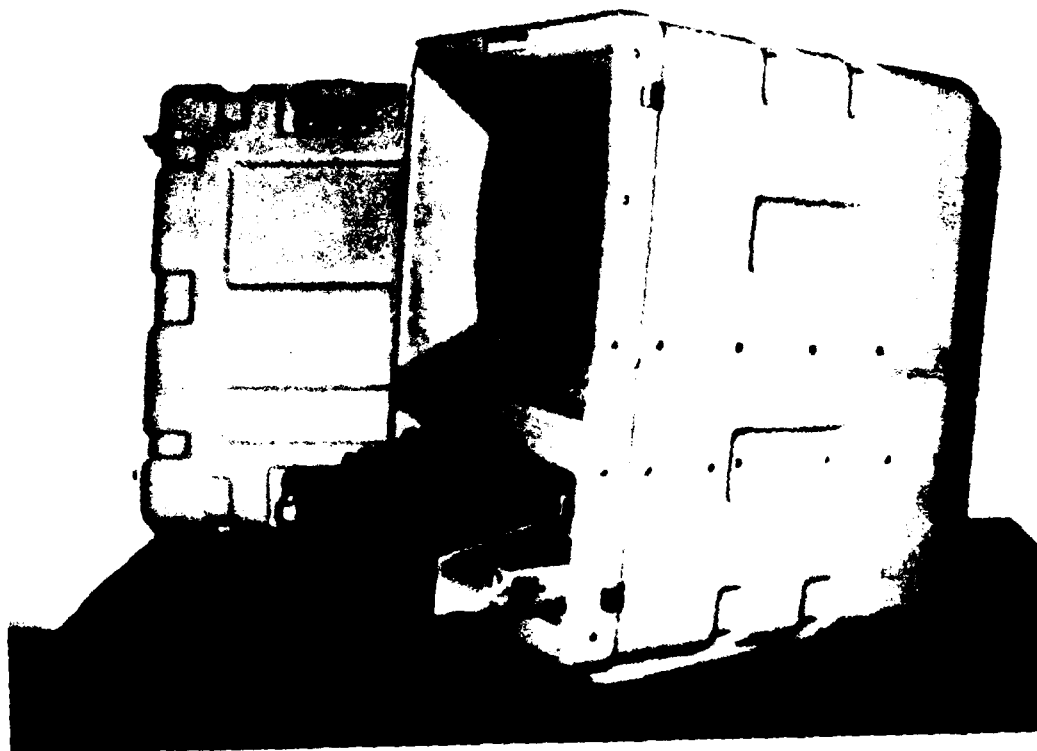


FIGURE 20

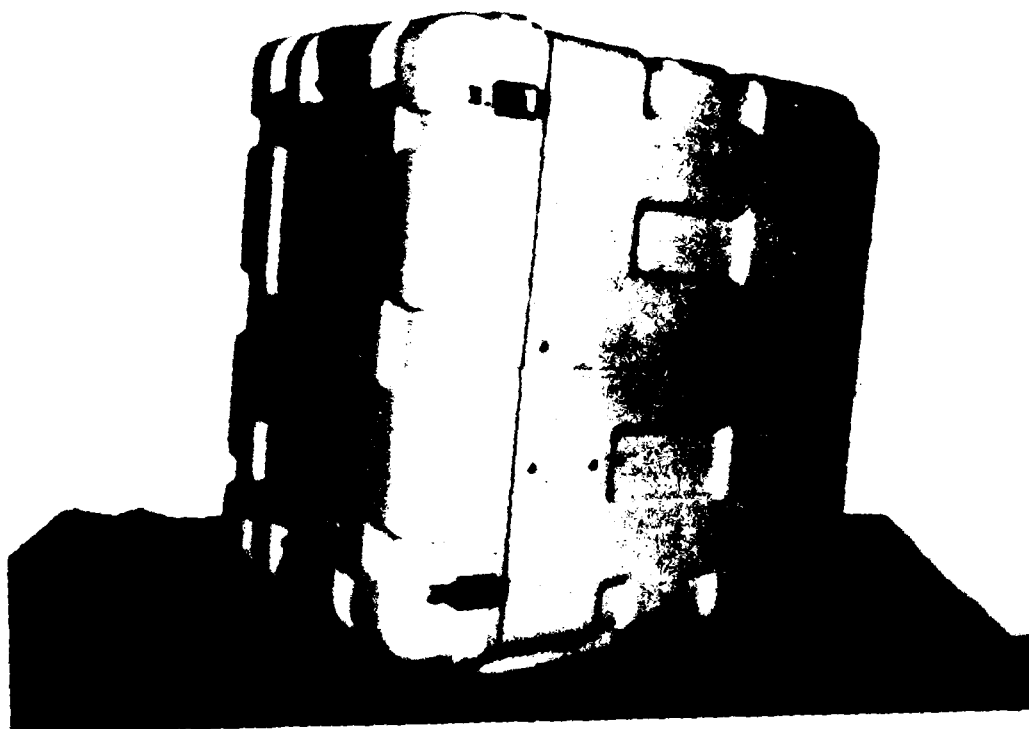


FIGURE 21

TABLE I. - MATERIAL PROPERTIES *

MATERIAL	HIGH IMPACT ABS	ACRYLIC-PVC ALLOY	POLYCARBONATE
TENSILE STRENGTH AT BREAK, PSI	4800 - 6300	6500	9500
ELONGATION AT BREAK, %	5 - 70	100	110
TENSILE YIELD STRENGTH, PSI	4000 - 5500	—	9000
FLEXURAL YIELD STRENGTH, PSI	8000-11,000	10,700	13,500
IZOD IMPACT, FT-LB/IN	6.5 - 7.5	15	14
HARDNESS - ROCKWELL	R85 - 105	R99 - 105	M70
DEFLECTION TEMPERATURE, ° F	210 - 225	177	280

* Source: Modern Plastics Encyclopedia, 1981-82 Edition, McGraw-Hill

APPENDIX A

StepanStepan Chemical Company
Urethane DepartmentEvanston, Illinois 6009
Telephone 312 446 7500**S****Technical Information
Bulletin****STEPANFOAM™ POLYURETHANE
FOAM SYSTEMS****SYSTEM:** STEPANFOAM HC-2/40 (Beam System)

TYPE: An integral skin (self-skinning), low density, high flow, molding formulation. Ideal for the molding of non-structural, decorative articles such as decorative beams and all types of add-on parts.

TYPICAL PROPERTIES:

Hand Mixing Ratio, A:B	1:1 by weight
Resin Temperature, °F.	70
Component A Temperature, °F.	80
Cream Time, sec.	40
Tack Free Time, sec.	160
Rise Time, sec.	195
Density, pcf	1.9

RECOMMENDED MACHINE PROCESSING CONDITIONS

Mix Ratio, A:B	1:1 by weight
Resin Temperature, °F.	70
Component A Temperature, °F.	80
Demold Time, min.	10-12

4/73

All polyurethane foam burns in varying degrees which in turn liberates toxic gases and should be evaluated in its final form on meeting existing standards in your industry.

The information presented herein is based on our own research and that of others and is believed to be correct. However, no warranty is expressed or implied. No statement herein extends any license, either expressed or implied, in connection with any patents issued or pending which may be the property of Stepan or others.

CHEMPOLUrethane Resins
Technical Data SheetJUNE, 1978
(Reissue of February, 1977)

CHEMPOL 30-1997/30-2025

DESCRIPTION:

A Polyether, Quasi-Prepolymer Flexible Urethane Foam System
Designed for Preformed or Pour-in-Place High Load Bearing
and High Dampening Packaging Applications.

DISTINGUISHING CHARACTERISTICS:

Low Compression Sets
Low Resiliency
Rapid Cure at Room Temperatures

TYPICAL RESIN PROPERTIES:

	<u>30-1997</u>	<u>30-2025</u>
Viscosity @ 25°C	1500 cps	1250 cps
Weight per Gallon	8.6 lbs.	9.7 lbs.

TYPICAL REACTION PROPERTIES:

Cream Time 20 seconds
Rise Time 120 seconds
Demold Time 10 minutes
Free-Rise Density* 3.0 pcf

MIX RATIO:

30-1997 100 parts by weight
30-2025 110 parts by weight

*The density values listed above are free-rise densities and should not be confused with overall density. Overall densities are always higher than free-rise density and take into account, skin formation, shape of part, packing and etc.

Freeman Chemical Corporation

A Subsidiary of H.H. Robertson Co.

Home Office: Port Washington, WI

Production Facilities: Saukville, WI - Chatham, VA - Marshall, TX - Burlington, IA

CENTRO CORPORATION

CHEMPOL 30-1997/3, 2025

PAGE 2

JUNE, 1978

TYPICAL PHYSICAL PROPERTIES:

Overall Molded Density 4.0 pcf

Compression Load Deflection (2" Thickness)

25% Deflection 1.15 psi

50% Deflection 2.0 psi

65% Deflection 3.4 psi

Compression Set (Final Cure)

(ASTM D-1564)

50% Deflection 20%

Tensile Strength 38 psi

Tear Strength 1.2 pli

Elongation 70%

STABILITY:

Minimum shelf life of six months when stored in tightly sealed containers.

STORAGE AND HANDLING:

To insure maximum foaming quality, both Chempol components of this urethane foam system should be mixed thoroughly at the same temperature as recommended for foaming before being used.

All efforts should be made to keep the two components as dry as possible. Incorporation of water into the 30-2025 will cause a viscosity and NCO stability problem. Water incorporated into the 30-1997 will cause an alteration in density and reaction rates when the two components are foamed. Therefore, containers should be sealed tightly during storage.

(Continued)

APPENDIX B

RECEIVED FEB 1 1982

Detroit Testing Laboratory, Inc.



8720 NORTHEAST AVENUE OAK PARK MICHIGAN 48237 313-396-2100

REPORT NUMBER	CLIENT'S ORDER	DATE REC'D.	REPORT DATE
111241 I	2999	11-11-81	1-26-82

REPORT FOR

Centro Corporation
1934 Stanley Avenue
Dayton, Ohio 45404

Attn: Dale Bazill

SUBJECT:

Report on Environmental, Shock and Vibration testing performed on two (2) video display terminals.

TEST PURPOSE:

To determine under laboratory test conditions, if the test samples meet the test specifications used throughout testing.

DESCRIPTION OF SAMPLES:

Two (2) Ruggedized Video Display Terminals, marked Sample A and B.

TEST SPECIFICATIONS:

Per Centro Corporation's test specification No. 114, Phase III Test plan for ruggedized video display terminal dated June 8, 1981, with reference to Mil. Std. 810-C.

TEST EQUIPMENT:

High Temperature, Low Temperature, Temperature Shock

- . . . One (1) temperature chamber, Thermotron Corp. Model SM16C, Serial No. 25263802.
- . . . One (1) Microcomputer Programmer, Thermotron Corp. Model No. 012003, Serial No. 7903243200007.

Vibration

- . . . Hewlett-Packard Vibration Control System; Model 5427A; S/N 173

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Centro Corporation

TEST EQUIPMENT: (Continued)

- . . . Ling Power Amplifier; Model 8008-8 SSPA S/N 85
- . . . Unholtz-Dickie 4000 Force Pound Shaker; Model TC 208; S/N 348
- . . . Endevco Accelerometer; Model 2221D; S/N CL 43; calibration: 7-16-81;
due: 7-16-82
- . . . Test Fixtures: Manufactured by: Detroit Testing Laboratory, Inc.

TEST PROCEDURE:

High Temperature

Test sample B was placed in the temperature chamber and the chamber was programmed to cycle per Mil. Std. 810-C, Method 501.1 Procedure II.

- Step 1 Prepare the test item in accordance with General Requirements, 3.2.
- Step 2 Raise the internal chamber temperature to 49°C (120°F).
- Step 3 Maintain internal chamber temperature for 6 hours at 49°C (120°F).
- Step 4 Raise the internal chamber temperature to 71°C (160°F) within a time period of 1 hour and then maintain at that temperature for 4 additional hours.
- Step 5 Lower the internal chamber temperature to 49°C (120°F) within a time period of 1 hour.
- Step 6 Repeat steps 3, 4, and 5 two additional times (making a total of three 12-hour cycles).

After the sample had completed the 36 hours of high temperature cycling, the sample was removed from the chamber. A visual inspection and an electrical performance check was then performed on the sample. As stated in specification 114C, paragraph 5.1 and 5.2.

TEST PROCEDURE:

Low Temperature

Test sample B was placed in the temperature chamber and the chamber was programmed to cycle per Mil. Std. 810-C, Method 502.1, Procedure I.

Centro Corporation

TEST PROCEDURE: (Continued)

A temperature of -70°F was maintained for a period of 24 hours. Next, the temperature of the chamber was adjusted to the lowest temperature under which the test item is designed to operate -50°F and allowed to stabilize for a period of four hours.

After the sample had completed the cycle, it was removed from the chamber. A visual inspection and an electrical performance check was then performed on the sample. As stated in specification 114C, paragraph 5.1 and 5.2.

TEST PROCEDURE:

Temperature Shock

Test sample B was placed in the temperature chamber and the chamber was programmed to cycle per Mil. Std. 810-C, Method 503.1, Procedure 1.

- Step 1 Prepare the test item in accordance with General Requirements 3.2 and raise the internal chamber temperature to 71°C (160°F). Maintain for a period of not less than 4 hours or until the test item stabilizes.
- Step 2 At the conclusion of this time period, the test item shall be transferred, within 5 minutes, to a cold chamber with an internal chamber temperature of -57°C (-70°F).
- Step 3 The test item shall be exposed to this temperature for a period of not less than 4 hours or until the test item stabilizes.
- Step 4 At the conclusion of this time period, the test item shall, within 5 minutes, be returned to high temperature chamber maintained at 71°C (160°F).
- Step 5 The test item shall be exposed to this temperature for a period of not less than 4 hours or until the test item stabilizes.
- Step 6 Repeat steps 2 through 5.
- Step 7 Repeat steps 2 and 3.
- Step 8 Return the test item to standard ambient conditions and stabilize.

After the sample had completed this cycle, the sample was removed from the chamber. A visual inspection and an electrical performance check was then performed on the sample as stated in specification 114-C, paragraph 5.1 and 5.2.

Centro Corporation

TEST PROCEDURE:

Vibration

The test sample was mounted to the shaker in the vertical axis and vibrated per Procedure X, Mil. Std. 810-C, Method 514.2, Figure 514-7, Curve AA to ten hz., then Curve AV to 200 hz. The sample was vibrated for 1 hour and 24 minutes with a sweep time of 12 minutes. At the end of the vertical axis the sample was removed from the chamber and a visual inspection and an electrical performance check was performed.

This procedure was repeated in the horizontal and lateral axis for a total cycling time of 4 hours and 12 minutes.

After the cycling was completed, the sample was placed on the shaker in the vertical axis and prepared for Procedure XI. (Equipment transported as loose cargo bounce.) The sample was then bounced at an amplitude of 1 inch displacement, at a frequency of 284 rpm (5hz) for a period of a 1/2 hour. At the end of this period the sample was removed from the shaker and a visual and an electrical performance check was performed. This procedure was repeated on each face of the test sample for a total of 3 hours, six faces, a 1/2 hour per face.

TEST PROCEDURE:

Shock

Per Mil. Std. 810-C, Method 516.2, Procedure 3.4, Table 516.2-1, the sample was raised to a height of 46 inches from the floor and dropped onto two inches of plywood once on each face, edge, and corner for a total of 26 drops. After each drop, the unit was visually inspected and an electrical performance check was performed.

After sample A had completed the fungus test, it was mounted to the shaker for vibration, bounce testing, and then shock testing.

TEST RESULTS:

High Temperature: Sample B

The CRT showed no signs of physical damage; the grid pattern moved 1/16 inch off horizontal and vertical.

Low Temperature: Sample B

The CRT showed no signs of physical damage; the grid pattern remained 1/16 inch off horizontal and vertical.

Temperature Shock: Sample B

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Centro Corporation

TEST RESULTS: (Continued)

The CRT showed no signs of physical damage; the grid pattern remained 1/16 inch off horizontal and vertical.

Vibration: Sample B

After vertical axis, the CRT showed no signs of physical damage; grid pattern moved back to the original starting spot.

After Lateral axis, the CRT showed no signs of physical damage; the grid pattern did not move

After horizontal axis, the CRT showed no signs of damage; however, the grid pattern had moved to the left of the screen 1/8 inch and vertical lines lettered I, J, K, L, M, N, and O of figure 1 were not visible.

Detroit Testing Laboratory, Inc. contacted Centro Corp. and informed Douglas Winkeljohn of the problem. He instructed us to try connecting the ECP to test sample A that was in fungus testing. After doing so, the fungus sample showed the same pattern as test sample B. It was then determined that the cause of the problem was a bad ECP tester. We were then instructed to take apart the ECP tester and turn a horizontal sink control. After doing so, the problem cleared up and the pattern was back to normal except the pattern was 1/16 inch off horizontally and vertically.

Bounce Test: Sample B

Face 1 No physical damage, grid pattern was 1/8 inch off horizontal and vertical.

Face 2 No physical damage, grid pattern was 1/16 inch off horizontal and vertical.

Face 3 No physical damage, grid pattern was 1/8 inch off horizontal and vertical, and lines lettered I, J, K, L, M, N, and O were not visible (same problem with pattern as before). We turned the horizontal sink control on the ECP until the pattern was back to normal.

Face 4 No physical damage, grid pattern was normal.

Face 5 No physical damage, grid pattern is normal.

Face 6 No physical damage, grid pattern is 1/16 inch off horizontal and vertical.

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Ceruro Corporation

TEST RESULTS: (Continued)

Shock Test: Sample B

<u>Drop Number</u>	<u>Face, Corner, Edge</u>	<u>Movement off Grid Patterns</u>
1	Face	None
2	Face	None
3	Face	1/16" off horizontal and vertical
4	Face	None
5	Face	None
6	Face	None
1	Corner	None
2	Corner	1/8" off horizontal and vertical
3	Corner	1/16" off horizontal
4	Corner	None
5	Corner	None
6	Corner	None
7	Corner	None
8	Corner	None
1	Edge	None
2	Edge	None
3	Edge	1/8" off horizontal
4	Edge	None
5	Edge	1/8" off horizontal

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Centro Corporation

TEST RESULTS: (Continued)

Shock Test: Sample B

<u>Drop Number</u>	<u>Face, Corner, Edge</u>	<u>Movement off Grid Pattern</u>
6	Edge	None
7	Edge	None
8	Edge	3/16" off horizontal
9	Edge	None
10	Edge	None
11	Edge	None
12	Edge	None

Total of 26 drops. The movement of the grid pattern was adjusted after every drop (if needed) with the horizontal sink control on the EPC tester.

Fungus Test: Sample A

After removing the test sample from the chamber, an electrical performance test was performed. The grid pattern did not move after fungus testing.

Vibration Test: Sample A

After Vertical axis, the CRT showed no signs of physical damage; grid pattern was normal.

After Lateral axis, the CRT showed no signs of physical damage; grid pattern was normal.

After Horizontal axis, the CRT showed no signs physical damage; grid pattern was normal.

Bounce Test: Sample A

Face 1 No physical damage; grid pattern was off 1/16 inch horizontally.

Face 2 No physical damage; grid pattern was off 1/16 inch horizontally and vertically.

Face 3 No physical damage; grid pattern was normal.

Face 4 No physical damage; grid pattern was normal.

Detroit Testing Laboratory, Inc.

Report Number 111241 I
Date: 1-26-82
Page: 8

Centro Corporation

TEST RESULTS: (Continued)

Bounce Test: Sample A (Continued)

Face 5 No physical damage; grid pattern was normal.

Face 6 No physical damage; grid pattern was normal.

Shock Test: Sample A

<u>Drop Number</u>	<u>Face, Corner, Edge</u>	<u>Movement off Grid Pattern</u>
1	Face	None
2	Face	None
3	Face	None
4	Face	None
5	Face	None
6	Face	None
1	Corner	None
2	Corner	1/16" off horizontal
3	Corner	1/16" off horizontal
4	Corner	None
5	Corner	None
6	Corner	None
7	Corner	None
8	Corner	Drifted badly to left top corner of screen, verti- cal lines A & B are off screen
1	Edge	None
2	Edge	None

Detroit Testing Laboratory, Inc.

Report Number 111241 I
Date: 1-26-82
Page: 9

Centro Corporation

TEST RESULTS: (Continued)

Shock Test: Sample A (Continued)

<u>Drop Number</u>	<u>Face, Corner, Edge</u>	<u>Movement off Grid Pattern</u>
3	Edge	1/16" off horizontal
4	Edge	None
5	Edge	None
6	Edge	None
7	Edge	None
8	Edge	None
9	Edge	1/16" off horizontal
10	Edge	None
11	Edge	None
12	Edge	None

Total of 26 drops. After drop number 8 of the corner, Detroit Testing Laboratory, Inc. contacted Centro Corp. and informed Douglas Winkeljohn of the problem. We connected the ECP tester to sample B and the pattern was the same. We then turned the horizontal sink on the ECP tester until the grid pattern pattern was normal.

CONCLUSIONS:

The two CRTs passed all testing performed by Detroit Testing Laboratory, Inc. All of the major problems that were encountered during testing were found to be due to the ECP tester

Detroit Testing Laboratory, Inc

Report Number 111241 I

Date: 1-26-82

Page: 10

Centro Corporation

DISPOSITION OF SAMPLES:

The two CRTs and the ECP tester were returned to Centro Corp. at the end of all testing.

DETROIT TESTING LABORATORY, INC.

James Sabotka

James Sabotka
Technician

Thomas Wharam

Thomas Wharam, Manager
Vibration, Shock & Electronics Testing

JS/TW/pcr

RECEIVED FEB 1 1982

Detroit Testing Laboratory, Inc.



8720 NORTHEAST AVENUE OAK PARK, MICHIGAN 48237 TEL 395-2111

REPORT NUMBER	CLIENT'S ORDER	DATE REC'D.	REPORT DATE
111241-I			1/19/82

REPORT FOR

The Centro Corporation
1934 Stanley Avenue
Dayton, Ohio 45404

Attn: Mr. Walter C. Klank

SUBJECT:

Report on fungus test.

PURPOSE OF TEST:

To determine the resistance of the submitted specimen to fungus attack.

DESCRIPTION OF SAMPLE: One (1) piece, Video Display terminal in foam rubber.

TEST SPECIFICATION: MIL-STD-810C, Method 508.1 Procedure I.

TEST EQUIPMENT:

Sterile distilled water
Sterile needles
Sterile flasks 125 ml
Sterile solid glass beads (approximately 5 in diameter)
Sterile glass wool
Sterile sprayer, 250 ml, Sargent No. 18887-00-
Electric Autoclave, Wisconsin Foundry No. 25X
Incubation Cabinet, Thermotron, Model No. 32-C
Mini-Max, Serial No. 25-3330-04

(CONTINUED)

TEST PROCEDURE:

In preparing the fungi cultures, the following fungi were used:

	<u>ATCC No.</u>	<u>QMC No.</u>
Aspergillus Niger	9642	386
Aspergillus Flavus	9643	380
Aspergillus Versicolor	11730	432
Penicillium Funiculosum	11797	474
Cheatomium Globosum	6205	459

Subculture of the above fungi were prepared by depositing spores of each stock culture on potatoe dextrose agar, except the subculture of cheatomium globosum was cultured on strip of filter paper on the surface of mineral salt agar. All subcultures were placed in incubation chamber at a temperature of 86°F for a time period of two (2) weeks prior to the test. A spore suspension of each of the five fungi was prepared by pouring into one subculture of each fungus a 10 ml-portion of sterile distilled water containing nontoxic wetting agent. The spores were brought into suspension by gently rubbing of the spores with a sterile platinum inoculating wire without disturbing the agar surface. The spore charge was poured into a sterile 125 ml flask containing 45 ml of sterile water and 50-75 solid glass beads, 5 mm in diameter. The flask was shaken vigorously to liberate the spores from fruiting bodies and to break the spore clumps.

The dispersed fungal spore suspension was filtered through a 6 mm layer of glass wool into a sterile flask to remove large mycelial filaments and clumps of agar.

The filtered spore suspension was centrifuged aseptically and the supernatant liquid was discarded. The residue was resuspended in 50 ml of sterile water and centrifuged. The spores obtained of each of the fungi were washed in this manner three (3) times.

The final washed residue was diluted with sterile mineral - salt solution in such a manner that the resultant spore suspension contained $1,000,000 \pm 200,000$ spores per ml. This operation was repeated for each organism used in the test. Equal volumes of the resultant suspension were blended to obtain the final mixed spore suspension. The entire surface of the submitted specimen was inoculated by spraying with the mixed spore suspension by means of the sterile Sargent Sprayer. Three (3) viability control samples, culture Petri dishes with pieces of sterilized filter paper (1-inch square) on hardened mineral-salt agar, were inoculated with the same spore suspension that was sprayed on the test specimens.

In addition to the viability of inoculum control, three (3) control items consisting of cotton duct, 8.25 ounce strips, 1.25 inches wide, were dipped into a solution containing 10% glycerol, 0.1% potassium dihydrogen orthophosphate, 0.1% ammonium nitrate, 0.025% magnesium sulfate, and 0.05% yeast extract. The excess liquid was removed and the strips were hung to air dry before being inoculated and placed into the chamber.

TEST PROCEDURE: (continued)

The tested specimens, viability and control samples were subjected to the same condition under cyclic temperature and humidity conditions to include 20 hours of relative humidity at $95 \pm 5\%$ at an air temperature of $86 \pm 2^\circ\text{F}$, followed by 4 hours of 100% relative humidity at $77 \pm 2^\circ\text{F}$. The test specimen and control samples were incubated for a time period of 28 days.

TEST RESULTS:

The test fungi on viability and control samples produced satisfactory fungus growth after seven (7) days exposure.

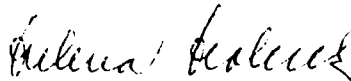
A visual examination of the tested specimens revealed the following results:

The tested specimen showed no evidence of fungus growth on its significant surface.

DISPOSITION OF SAMPLE:

Back to "I" Department on 1/18/82 for functional test.

DETROIT TESTING LABORATORY, INC.



Helena Holecek, Manager
Environmental Testing

HH/jek

RECEIVED AUG 26 1983

Detroit Testing Laboratory, Inc.



8720 NORTHEAST AVENUE OAK PARK MICHIGAN 48237 (313) 398-2100

REPORT NUMBER	304383-1	CLIENT'S ORDER PO# 3032	DATE REC'D. 4/22/83	REPORT DATE 8/23/83
REPORT FOR				

Centro-Corporation
1934 Stanley Avenue
Dayton, Ohio 45404

Attn: Mr. Douglas M. Winkeljohn

SUBJECT:

Report of testing performed on one (1) video display terminal.

TEST PURPOSE:

To assist in the determination as to whether the test specimen meets the requirements of the applicable test specification.

DESCRIPTION OF SAMPLE:

The client submitted for testing one (1) Ruggedized Video Display Terminal Model # C-5785, Serial #3, unit was supplied with a high voltage power supply and drawer installed.

TEST SPECIFICATION:

Per Centro-Corporation specification No. 124, Revision A, Dated April 21, 1983, Project No. C-442, Referenced to MIL-STD-810-C.

WORK PERFORMED:

Listed in the order that tests were performed.

Test	Applicable Paragraph
High Temperature	4.2.2
Low Temperature	4.2.3
Temperature Shock	4.2.4
Vibration	4.2.5
Shock	4.2.6

TEST EQUIPMENT:

High & Low Temperature: Temperature Chamber, Thermotron, Model #SM-16C,
Serial No. 25263802, calibrated 12/82

Temperature Shock: Temperature Chamber, Thermotron, Model #SM32, Serial #25333004
Temperature Chamber, Thermotron, Model #SM16, Serial #25263802,
calibrated 12/82

Vibration: Hewlett-Packard Vibration control system, Model 5427A, Serial No. 173
Ling Power Amplifier, Model 8008-8 SSPA, Serial No. 85
Unholtz-Dickie 4000 force pound shaker, Model TC 208, Serial No. 348
Endevco Accelerometer, Model 2220-C, Serial No. CS 93, calibrated 4/19/83

Shock: One (1) hoist
One (1) quick-release Hook

TEST PROCEDURE:

High Temperature:

The test specimen was placed within a temperature controlled chamber while at room ambient conditions ($75 \pm 10^\circ\text{F}$). The internal temperature was then brought to 120°F at a rate not exceeding 1°F per minute. The specimen was then subjected to three (3) temperature cycles as follows:

<u>Step</u>	<u>Temperature</u>	<u>Duration</u>
1	120°F	6 hours
2	$120 - 160^\circ\text{F}$	1 hour
3	160°F	6 hours
4	$160 - 120^\circ\text{F}$	1 hour

Upon completion the specimen underwent a performance test.

Low Temperature:

The unit was placed in a temperature chamber at an ambient temperature of $75 \pm 10^\circ\text{F}$. The chamber temperature was then lowered to -70°F at a rate not exceeding $.5^\circ\text{F}$ per minute. The unit was allowed to stabilize for a duration of 4 hours at this temperature and then soaked for an additional 24 hours.

The unit was then stabilized for 24 hours at room ambient conditions where upon a functional performance check was made.

(CONTINUED)

TEST PROCEDURE: (continued)

Temperature Shock:

The specimen was subjected to three (3) thermo-shock cycles as outlined below:

<u>Step</u>	<u>Temperature</u>	<u>Duration</u>
1	160°F	4 hours
2	160° to -70°F	Less Than 5 minutes
3	-70 °F	4 hours
4	-70 to 160°F	Less than 5 minutes
5	end one cycle	

Upon completion the specimen underwent a functional performance check.

Vibration: Procedure X, Secured Cargo

The unit was secured to the vibration table in the vertical axis. It was then vibrated for eighty-four (84) minutes at the following test levels:

5 Hz to 10 Hz at .375 g
10 Hz to 38 Hz at 1.5 g
38 Hz to 50 Hz at .02 DA
50 Hz to 200 Hz at 2.5 g

This frequency range 5 - 200 - 5 Hz, was logarithmically swept in twelve (12) minutes.

The above procedure was then repeated in the longitudinal and lateral axes. Total time of vibration was 252 minutes (84 minutes each axis).

After each axis of vibration the unit was checked for performance.

Vibration: Procedure XI, Loose Cargo

The bottom of the test platform was covered with 1/2 inch plywood. Restraints were then placed around the test unit to keep it on the platform.

The unit was then bounced at an amplitude of one (1) inch peak to peak at a frequency of five (5) Hz. At the end of each 1/2 hour period the unit was turned to rest on a different face. The unit was bounced on each of its six (6) faces. Total time of the test was three (3) hours. At the end of each face, the unit was checked for performance.

TEST PROCEDURE: (continued)

Shock:

The specimen was subjected to one free fall impact from a height of 48" on each face, corner and edge for a total of 26 impacts. The impact surface was a 2" thick plywood panel supported by a concrete floor.

The specimen was raised by means of a hoist then adjusted for proper position referenced to the impact plane. A quick release mechanism was then activated to allow the specimen to be suddenly released and free fall to the impact surface.

After each drop a functional performance test was performed.

TEST RESULTS:

High and Low Temperature:

There was no visual or electrical damage after testing.

Temperature Shock:

There was no visual damage to the test unit. However no pattern would appear on the screen of the CRT, after the character sequence given in figure 1 was inserted.

The unit was returned to Centro for examination. It was then returned to Detroit Testing Laboratory for completion of the test schedule.

Vibration:

Secured Cargo

There was no visual damage after testing. No patterns would appear on the screen of the CRT after the character sequence given in figure 1 was inserted. The unit was returned to Centro for examination. It was then returned to Detroit Testing Laboratory for completion of the test schedule.

Loose Cargo

There was no visual damage after testing. After four (4) faces of vibration no pattern would appear on the CRT. The unit was returned to Centro for examination. It was then returned to Detroit Testing Laboratory for completion of the test schedule.

(CONTINUED)

TEST RESULTS: (continued)

Shock:

During the second drop two of the latches broke off the case of the unit.

During the eighth drop the spacebar broke off of the keyboard.

There was no electrical damage after any of the drops.

TEST CONCLUSION:

No final conclusions will be drawn by Detroit Testing Laboratory, Inc.

DISPOSITION OF SAMPLE:

Returned to client.

DETROIT TESTING LABORATORY, INC.

Jim Sabotka

Jim Sabotka, Senior Technician

William E. Kocsis

William E. Kocsis, Manager
Vibration, Shock & Electronics Testing

JS/WEK/jek

PREPARED BY
D. Winkeljohn

CHECKED BY

APPROVED BY



DAYTON, OHIO

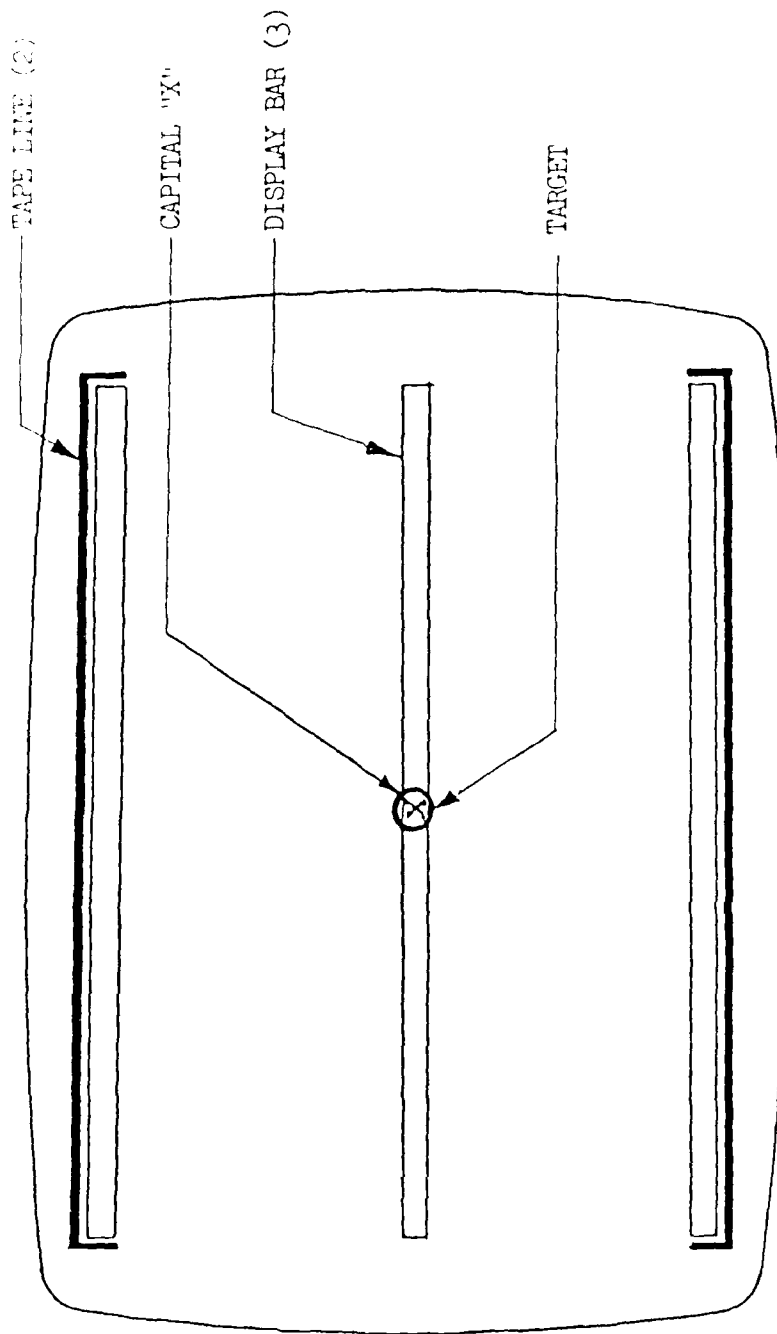
SPECIFICATION NO. 124
REVISION "A" (Cont.)

PAGE
1 of 1

Project No.
100-100000

Date
April 21, 1964

Revised 5/16/64



INPUT SEQUENCE: (ESC) G D (ESC) = + 8 (ESC) G D (ESC) = 7 6 (ESC) G D (ESC) = + 1 X (ESC) = 1 7

(ESC) IS KEY MARKED ESC

7 IS SPACE BAR

HOLD DOWN SHIFT KEY FOR ALL KEYSTROKES EXCEPT "7"

TYPE (ESC)+ TO ERASE AND START OVER

FIGURE 1

ORIGINAL EQUIPMENT SET TEST DISPLAY

RECEIVED JUN 27 1983

Detroit Testing Laboratory, Inc.



8720 NORTHEND AVENUE OAK PARK MICHIGAN 48237 (313) 398-2100

PORT NUMBER	CLIENT'S ORDER	DATE REC'D	REPORT DATE
304332 J	3031	4-22-83	6-23-83

PORT FOR

CENTRO CORPORATION
1934 Stanley Avenue
Dayton, Ohio 45404

Attn: Mr. Walter Klank

SUBJECT:

Report on fungus test.

PURPOSE:

To determine the resistance of the submitted specimen to fungus attack.

DESCRIPTION OF SAMPLE:

The client submitted one (1) piece, test specimen, marked #1.

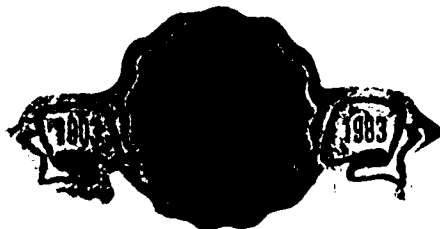
TEST SPECIFICATION:

MIL-STD-810C, Method 508.1

TEST EQUIPMENT:

Sterile distilled water
Sterile needles
Sterile flask; 125 ml.
Sterile solid beads (approximately 5 mm in diameter)
Sterile glass wool
Sterile Sprayer; 250 ml; Sargent No. S 18887-00
Electric Autoclave; Wisconsin Foundry; No. 25X
Incubation Chamber; Thermotron; Model SM 32C Mini-Max; Serial No. 25 3330-04

CONTINUED...



77

ENTRO CORPORATION

TEST PROCEDURE:

In preparing the fungi cultures, the following fungi were used:

	<u>ATCC No.:</u>	<u>QMC No.</u>
Aspergillus niger	9642	386
Aspergillus flavus	9643	380
Aspergillus versicolor	11730	432
Penicillium Funiculosum	11797	474
Chaetomium Globosum	6205	459

Subculture of the above fungi were prepared by depositing spores of each stock culture on potato dextrose agar, except the subculture of chaetomium globosum was cultured on a strip of filter paper on the surface of mineral salt agar. All subcultures were placed in incubation cabinet at a temperature of 86 °F for a time period of two (2) weeks prior to the test.

A spore suspension of each of the five fungi was prepared by pouring into one subculture of each fungus a 10 ml. portion of sterile distilled water, containing nontoxic wetting agent.

The spores were brought into suspension by gently rubbing of the spores with a sterile platinum inoculating wire without disturbing the agar surface. The spore charge was poured into a sterile 125 ml. flask containing 45 ml. of sterile water and 50-75 solid glass beads, 5 mm in diameter.

The flask was shaken vigorously to liberate the spores from the fruiting bodies and to break the spore clumps.

The dispersed fungal spore suspension was filtered through a 6 mm layer of glass wool into a sterile flask to remove large mycelial filaments and clumps of agar.

The filtered spore suspension was centrifuged aseptically and the supernatant liquid was discarded.

The residue was resusptent in 50 ml of sterile water and centrifuged. The spores obtained of each of the fungi were washed in this manner three times. The final washed residue was diluted with sterile mineral-salt solution in such a manner that the resultant spore suspension contained 1,000,000 ± 200,000 spores per ml. This operation was repeated for each organism used in the test.

CENTRO CORPORATION

TEST PROCEDURE: (Continued)

Equal volumes of the resultant suspension were blended to obtain the final mixed spore suspension.

The entire surface of the submitted specimen was inoculated by spraying with the mixed spore suspension by means of the sterile Sargent sprayer.

Two (2) viability control samples, culture Petri dishes with pieces of sterilized filter paper (1 inch square) on hardened mineral salt agar, were inoculated with the same spore suspension that was sprayed on the test specimen.

In addition to the viability of inoculum control, three (3) control items consisting of cotton duct 8.25 ounce strips, 1.25 inches wide, were dipped into a solution containing 10% glycol, 0.1% potassium dihydrogen orthophosphate, 0.1% ammonium nitrate, 0.025% magnesium sulfate, and 0.05% yeast extract.

The excess liquid was removed and the strips were hung to air dry before being inoculated and placed into the chamber.

The test specimen, viability and control samples were subjected to the same test conditions under cyclic temperature and humidity conditions to include 20 hours of relative humidity of $95 \pm 5\%$ at an air temperature of $86 \pm 2^\circ\text{F}$ followed by 4 hours of 100% relative humidity at $77^\circ \pm 2^\circ\text{F}$.

The test specimen and control samples were inoculated for a time period of 28 days.

TEST RESULTS:

The test fungi on viability and control samples produced satisfactory fungus growth after seven (7) days exposure.

A visual examination of the test specimen revealed that no fungus growth was evident on the significant surface of the test specimen after 28 days incubation period.

CONTINUED

Detroit Testing Laboratory, Inc.

CENTRO CORPORATION

Report Number 304382 J

Page -4-

Date: 6-23-83

SAMPLE DISPOSITION:

The tested specimen will be returned to the client by U.P.S. on 6-23-83.

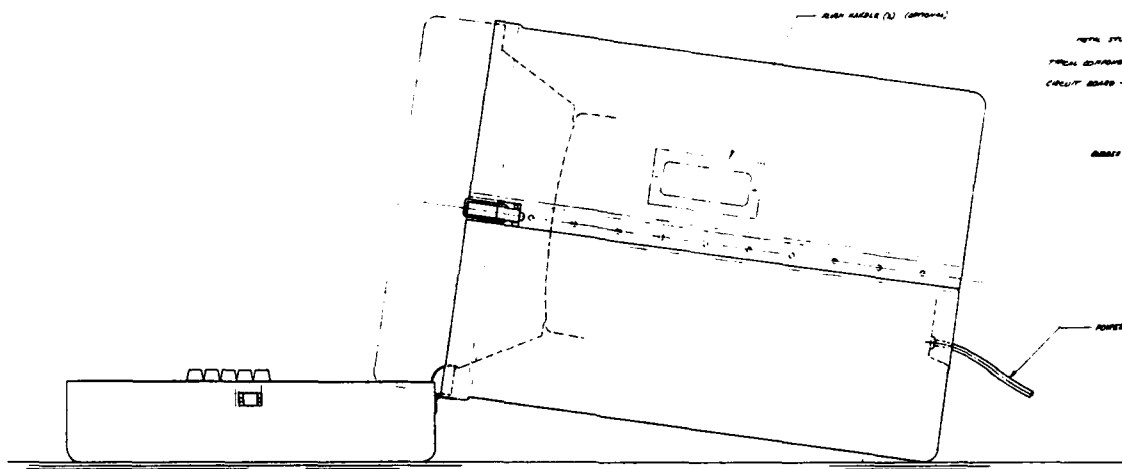
DETROIT TESTING LABORATORY, INC.

Helena Holecek
Helena Holecek, Manager
Environmental Testing

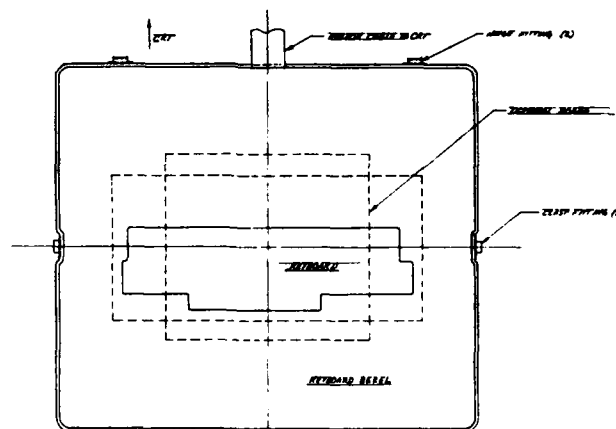
HH/jk

1

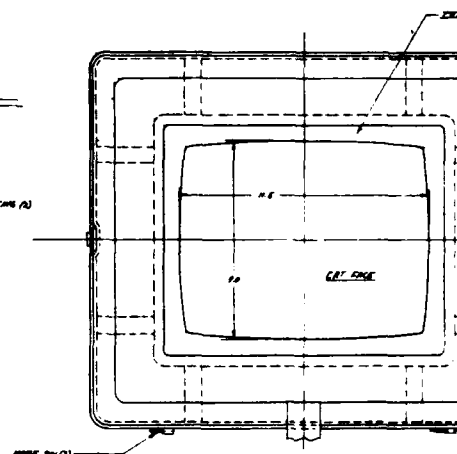
APPENDIX C



SIDE VIEW - TERMINAL DEPLOYED

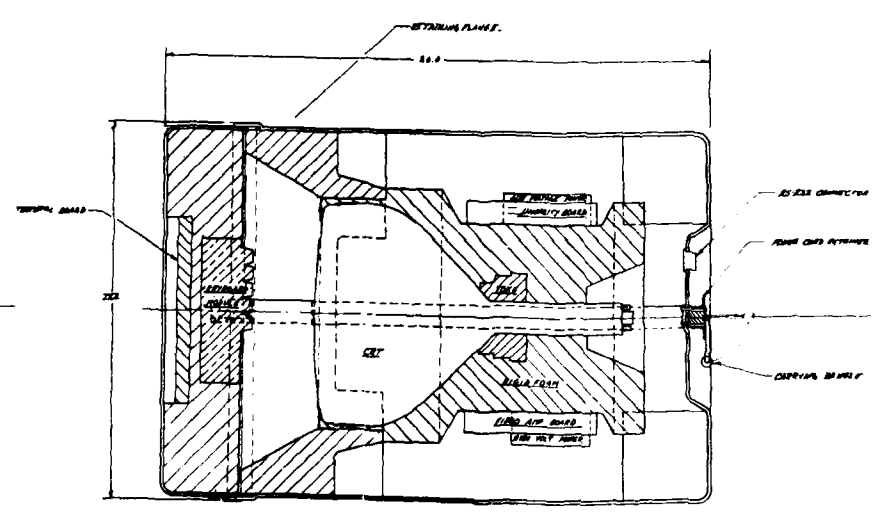
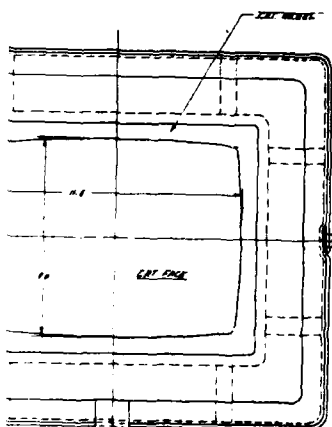
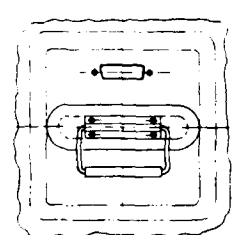
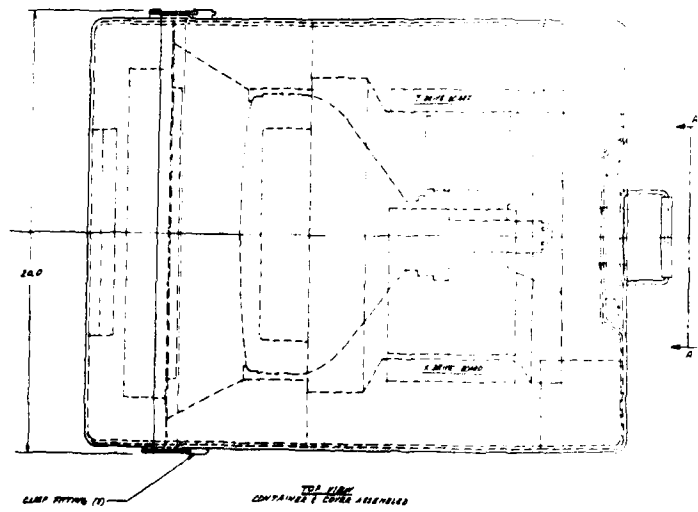
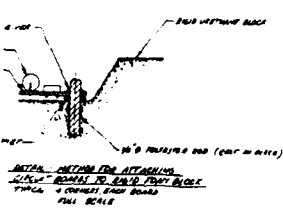


COVER (ALUMINUM) MOUNT
1/4" X 1/2" X 1/4"



COVER (ALUMINUM) MOUNT
1/4" X 1/2" X 1/4"

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PROPERTY OF CENTRO CORPORATION
UNLAWFUL TO REPRODUCE OR
TRANSMIT IN ANY MANNER
WITHOUT WRITTEN PERMISSION
OF CENTRO CORPORATION

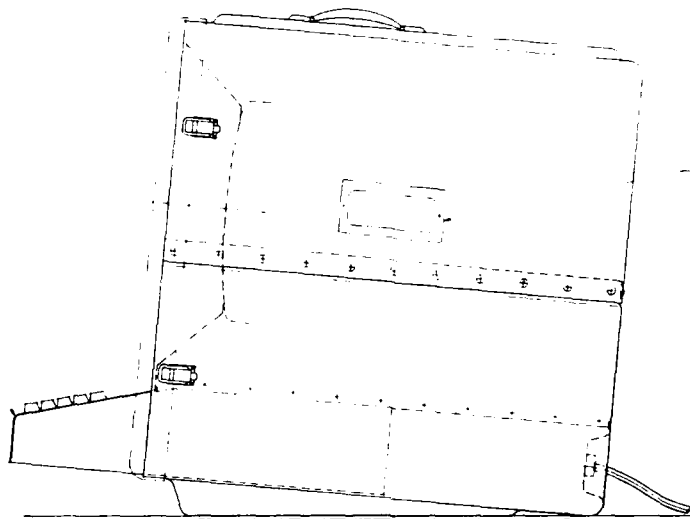


SEE CONTINUOUS
FOR OTHER VIEWS OF THIS UNIT
DIMENSIONS SHOWN TYPICAL

VIDEO TUBE
CONTAINER & COVER ASSEMBLY

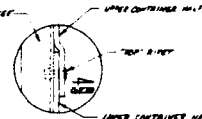
WORKING STANDARDS DIMENSIONS AND APPLICABLE		MATERIALS DIMENSIONS AND APPLICABLE		PARTS LIST DIMENSIONS AND APPLICABLE		CONCEPTUAL DRAWING - RUGGEDIZED VIDEO TERMINAL CONCEPT #1 - KEYBOARD IN COVER DIMENSIONS AND APPLICABLE		CENTRO CORPORATION C-5510 DIMENSIONS AND APPLICABLE	
--	--	--	--	---	--	--	--	--	--

KEYBOARD DETAIL



FLUSH HANDLE (2) OPTIONAL

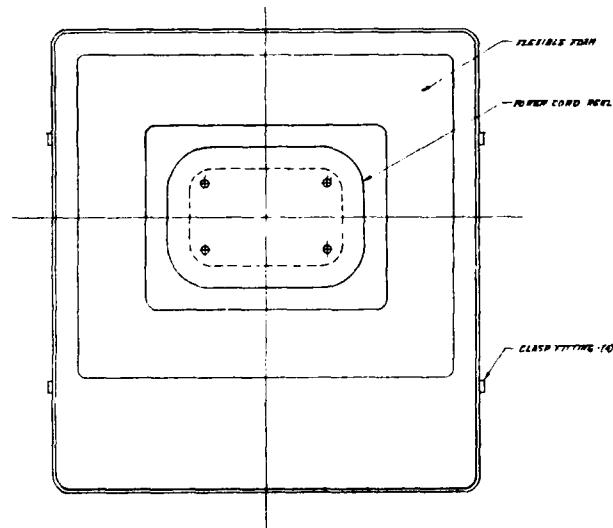
STITCHING (1) SEE



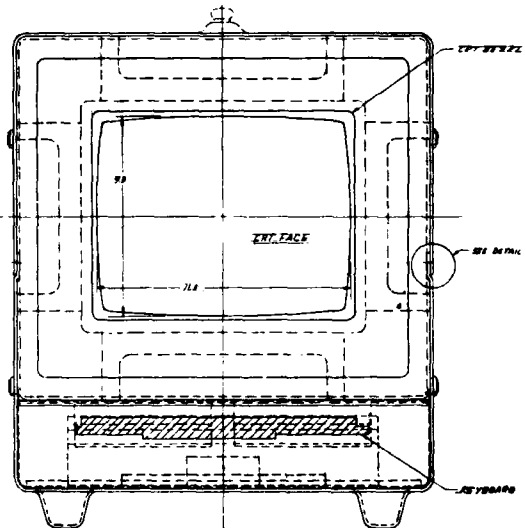
DETAIL A - CLOSE-UP
SHOWING OPTIONAL METHOD OF
ATTACHING HANDLE TO LID WITH
TYPICAL 'NUT-RIVET' ASSEMBLY

CLASP STITCHING (4)

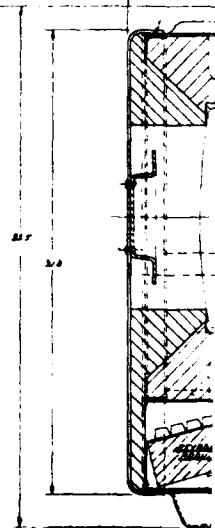
SIDE VIEW - TERMINAL CONTAINER
KEYBOARD TRAY ATTACHED - COVER REMOVED



INSIDE VIEW - COVER



EXT. CONTAINER
VIEW INTO FACE OF CAP
WITH COVER REMOVED



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CDR, AVRADCOM
ATTN: DRSAB-E
PO Box 209
1 St. Louis, MO 63166

Commandant
USAFAS
ATTN: ATSF-CD-DE
1 Fort Sill, OK 73503

CDR, ARRADCOM
ATTN: DRDAR-TSS, #59
2 Dover, NJ 07801

Commander
ATTN: DRCDE
5001 Eisenhower Ave.
1 Alexandria, VA 22333

CDR, ARRADCOM
ATTN: Mr. Harry E. Pebly, Jr.
PLASTEC Director
1 Dover, NJ 07801

Commandant
US Army Engineer School
ATTN: ATZA-TDL
1 Fort Belvoir, VA 22060

PM, FIREFINDER/REMBASS
ATTN: DRCPM-FER
1 Fort Monmouth, NJ 07703

Commander
US Army Logistics Ctr
ATTN: ATCL-MC
1 Fort Lee, VA 22801

Commander
US Army Satellite Comm Agcy
ATTN: DRCPM-SC-3
2 Fort Monmouth, NJ 07703

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HQ TRADOC
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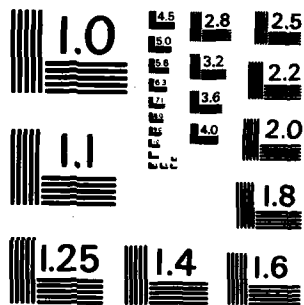
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Illus.-Tables, Contract DAMC46-81-C-0007
D/A Project: 2799825 (CECOM)
AMCMS Code: 69500R.235
Final Report, November 1980 to October 1983

Foam
Polyurethane resins
Plastics
Electronics
Minicomputers

A method of protectively mounting a cathode ray tube (CRT) and an electronic "drawer" in a video terminal utilizing a system of molded rigid and flexible urethane foam is described.

As a demonstration of the capabilities of the urethane foam suspension system to protect the CRT and electronics, a series of CRT packages and complete video terminals were designed, fabricated, and tested and shown to be successful.

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